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Most people will have the opportunity to view at least one total solar eclipse in their lifetime: 71 out of 228 eclipses were total (rather than partial or annular) in the 20th century and in the 21st century, the Earth will experience 68. But, as with any cosmic alignment, a not

inconsiderable amount of luck will play its part in whether you get to glimpse this rare celestial phenomenon or not.

Only a relatively tiny proportion of the surface of the Earth will experience the full occultation of the Sun by the Moon, for just a brief few minutes of the day, so being in the right place at the right time is vital. And we're completely at the whim of the weather: both the Faroe Islands and Svalbard will sit along the path of totality for the eclipse on 20 March this year, but while the Norwegian

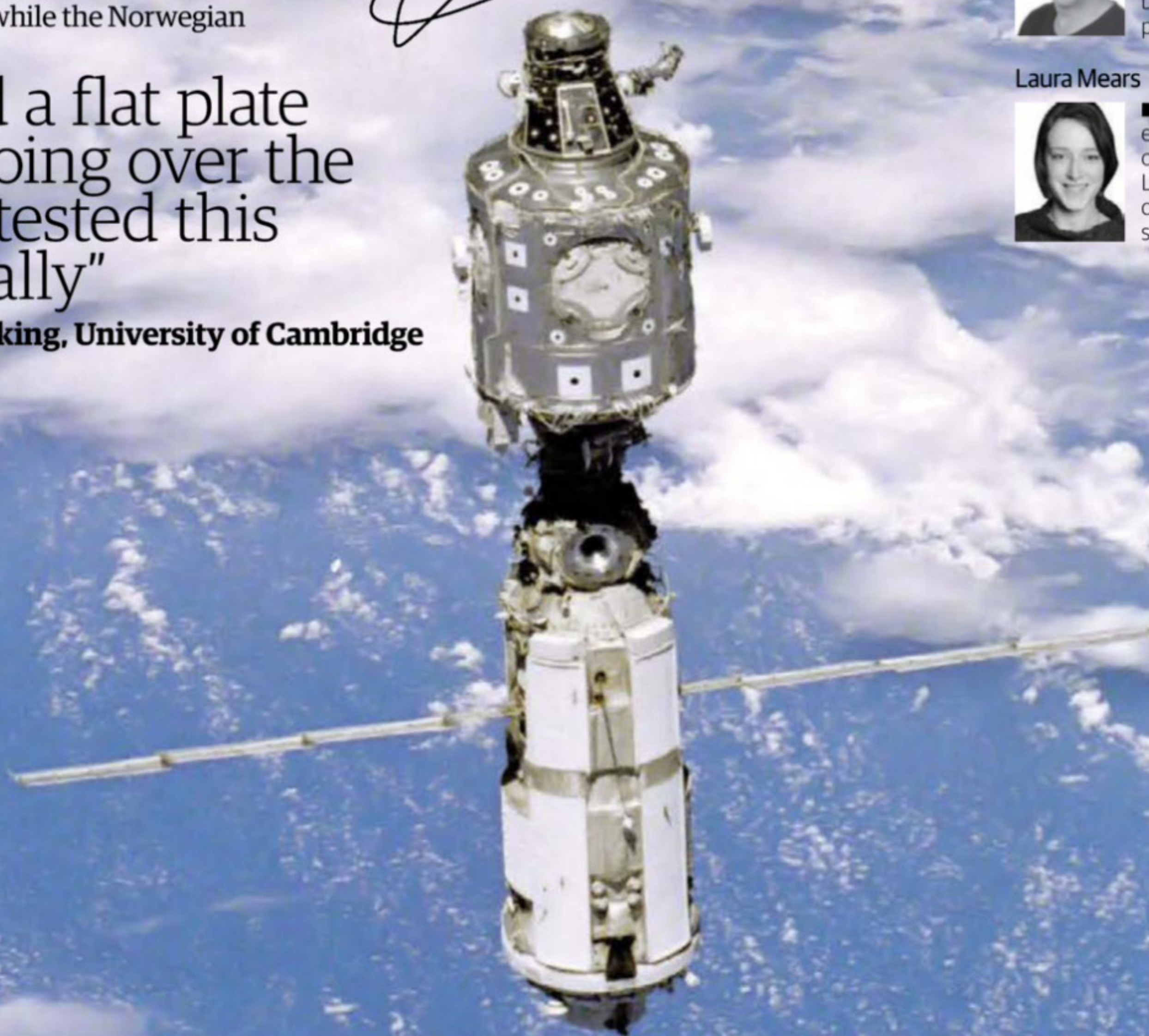
archipelago in the Arctic Circle is predicted bright and clear skies, the Danish islands further south are notoriously cloudy. It only takes one cloud obscuring the Sun at the wrong time to turn the event from a stunning stargazing spectacle into nothing more than a few minutes of bizarre night-time blackness.

Those outside of northern Europe might be missing the total eclipse this time around, but there will be opportunities to catch another one in the United States, South America, Australasia and South-East Asia at various times within the next decade. And between now and then, partial and annular eclipses pepper the celestial calendar - events no less fascinating in their own right.

Ben Biggs
Editor

"Is the world a flat plate with a sea going over the end? I have tested this experimentally"

Professor Stephen Hawking, University of Cambridge



The ISS in 1999, before future missions built the space station into what we see today

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Crew roster

Luis Villazon



■ Luis takes us on a tour of the Moon this month and points out some of his favourite spots.

Gemma Lavender



■ The only thing Gemma's looking forward to more than the eclipse is seeing her feature in print.

Jonny O'Callaghan



■ A moonwalk just won't cut it for Jonny: it's the Red Planet or bust for him, on page 18.

Laura Mears



■ After an exhaustive search of the universe, Laura counts out our top 100 space wonders.

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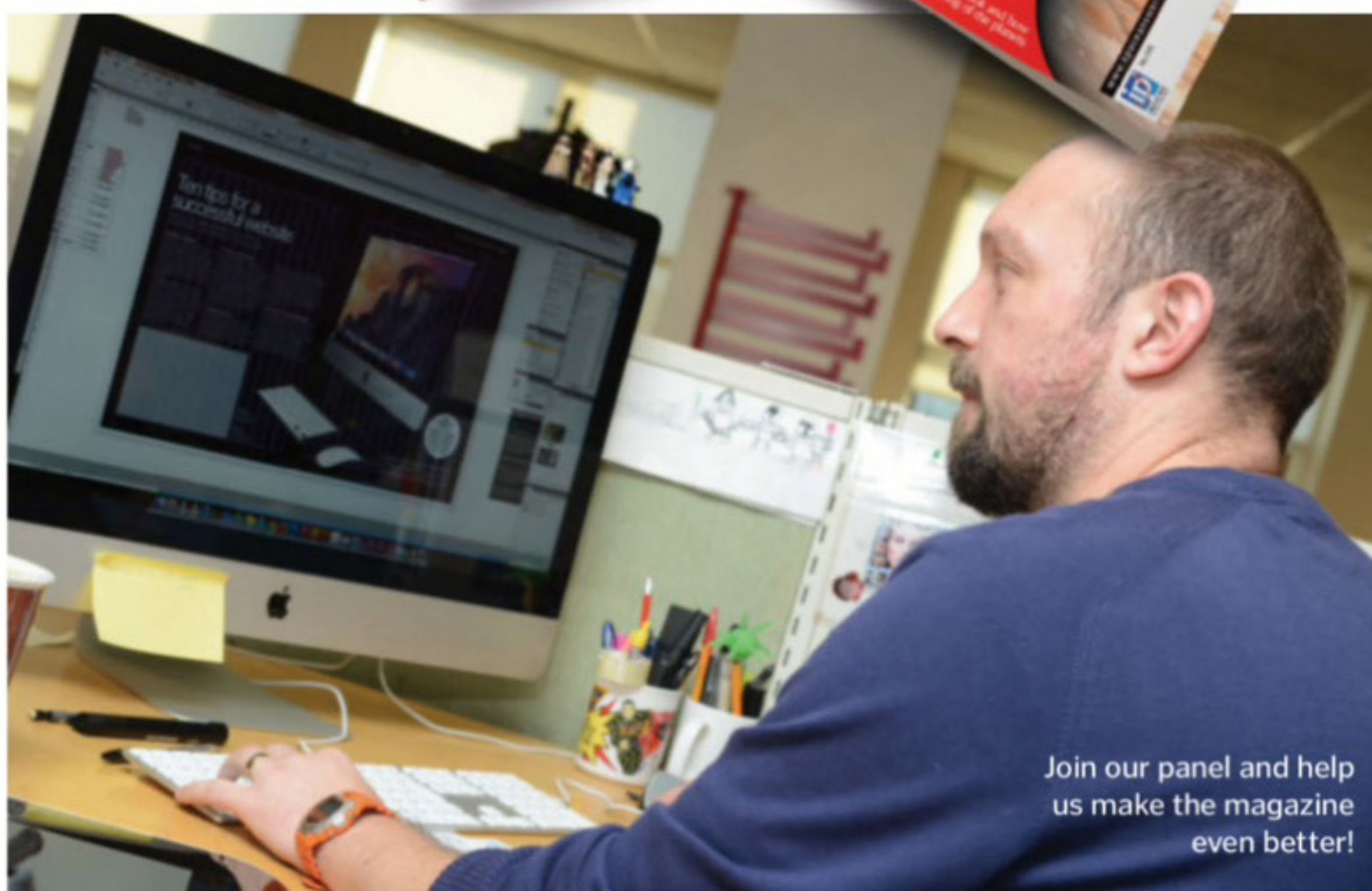
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Ben Biggs
Editor



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Stellar sting ray

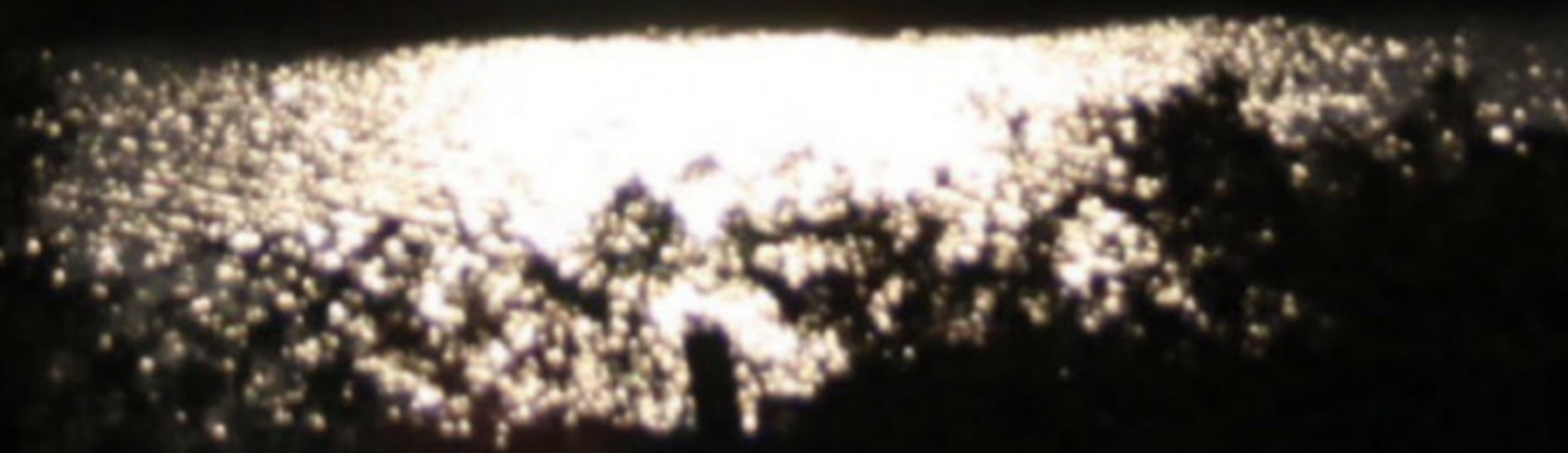
From the cosmic depths of 1,300 light years away, near the constellation Puppis, comes this deep space monster: cometary globule CG4 is actually a faint nebula that's tough to observe, but which has been picked out and highlighted by the European Southern Observatory's powerful Very Large Telescope (VLT). In fact, it wasn't discovered until 1976 and is currently being torn to pieces by nearby stars. It's known as 'God's Hand', but we think it looks much more like a giant stingray than anything else.





Dragon flight

Despite only being around for just over a decade, the private space company SpaceX is now a very well-established part of the space industry, with its own line of rockets and space vehicles capable of competing with the biggest government space agencies. Here we see one of its Falcon 9 rockets taking off from Cape Canaveral, carrying a Dragon resupply spacecraft with 1,680 kilograms (3,700 pounds) of supplies and instruments to the International Space Station (ISS).



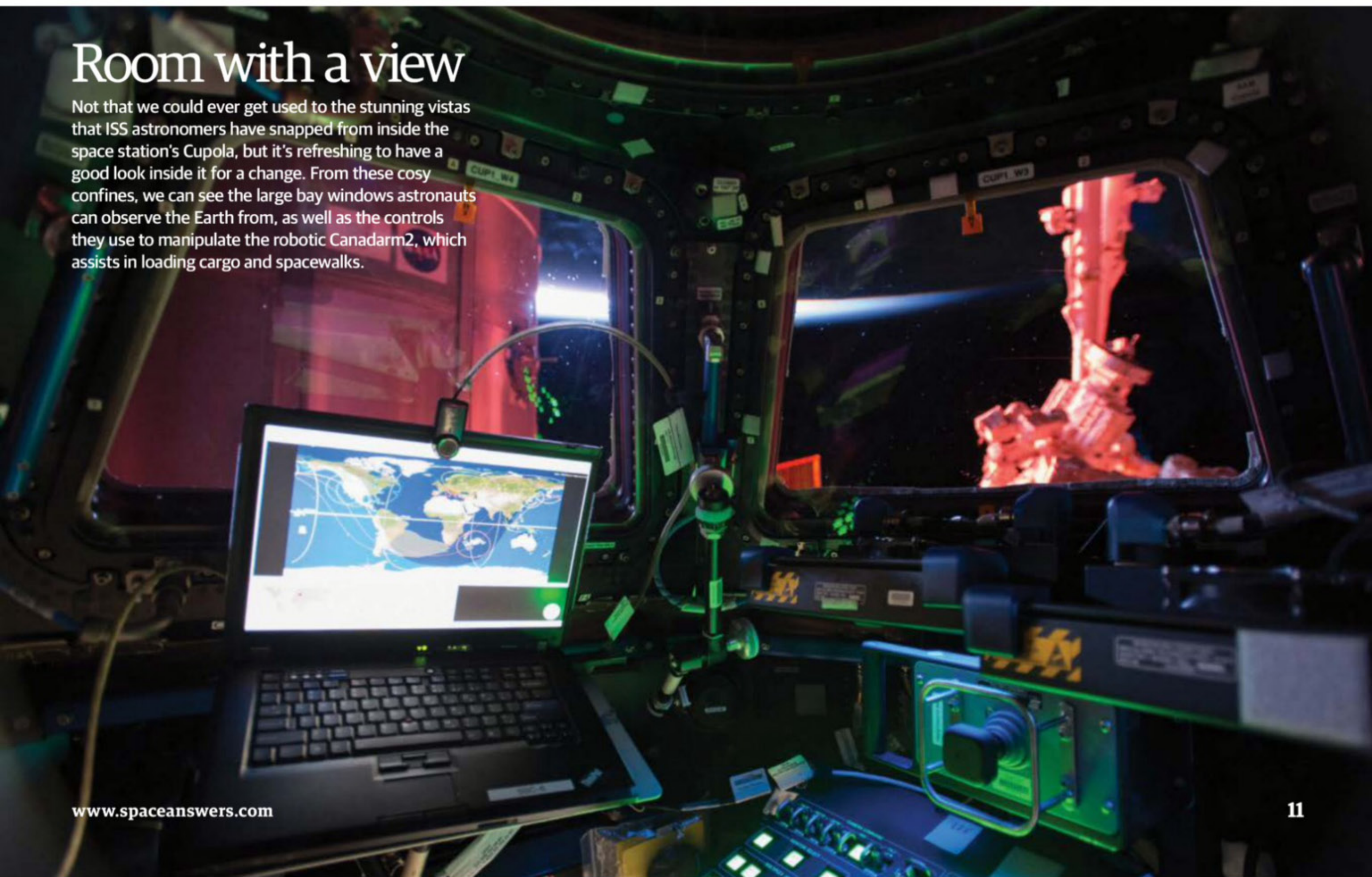


Spying on Curiosity

Martian orbiters like to keep tabs on the landers and rovers we've sent to the surface of the Red Planet, and the High Resolution Imaging Science Experiment (HiRISE) isn't missing out on the fun: this is a shot of an outcrop at the base of Mount Sharp known as the Pahrump Hills, and at the centre, highlighted by the blue square, is the Mars Science Laboratory rover Curiosity. You can even make out the shadow of the rover, which is cast to the upper right.

Room with a view

Not that we could ever get used to the stunning vistas that ISS astronauts have snapped from inside the space station's Cupola, but it's refreshing to have a good look inside it for a change. From these cosy confines, we can see the large bay windows astronauts can observe the Earth from, as well as the controls they use to manipulate the robotic Canadarm2, which assists in loading cargo and spacewalks.



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Moonset

This stunning long-exposure image was taken shortly after sunset, on the high-altitude plateau of the ESO's Paranal Observatory in Chile. On the backdrop of the fading orange rays from the Sun, the path of the crescent Moon can be seen to move down the lower left-hand side, while the movement of the stars are tracked, leaving trails across the sky. A meteor can also be seen, leaving a streak across the centre of the image.

© ESO, NASA

New study questions the origin of the universe

The European Space Agency's Planck satellite opens the lid on the birth of the universe itself thanks to new maps of polarised light

For years, scientists have operated under the belief that the first stars lit up the universe around 420 million years after the Big Bang, but a recent study by the European Space Agency has revealed they instead burst into life 560 million years later.

"This difference of 140 million years might not seem that significant in the context of the 13.8-billion-year history of the cosmos, but proportionately it's a very big change in our understanding of how certain key events progressed at the earliest epochs," said Professor George Efstathiou, one of the leaders of the Planck Science Collaboration.

The study, which has been using the now deactivated Planck spacecraft to create 'maps' of polarised light, is focused on measuring the afterglow of the Big Bang itself. Otherwise known

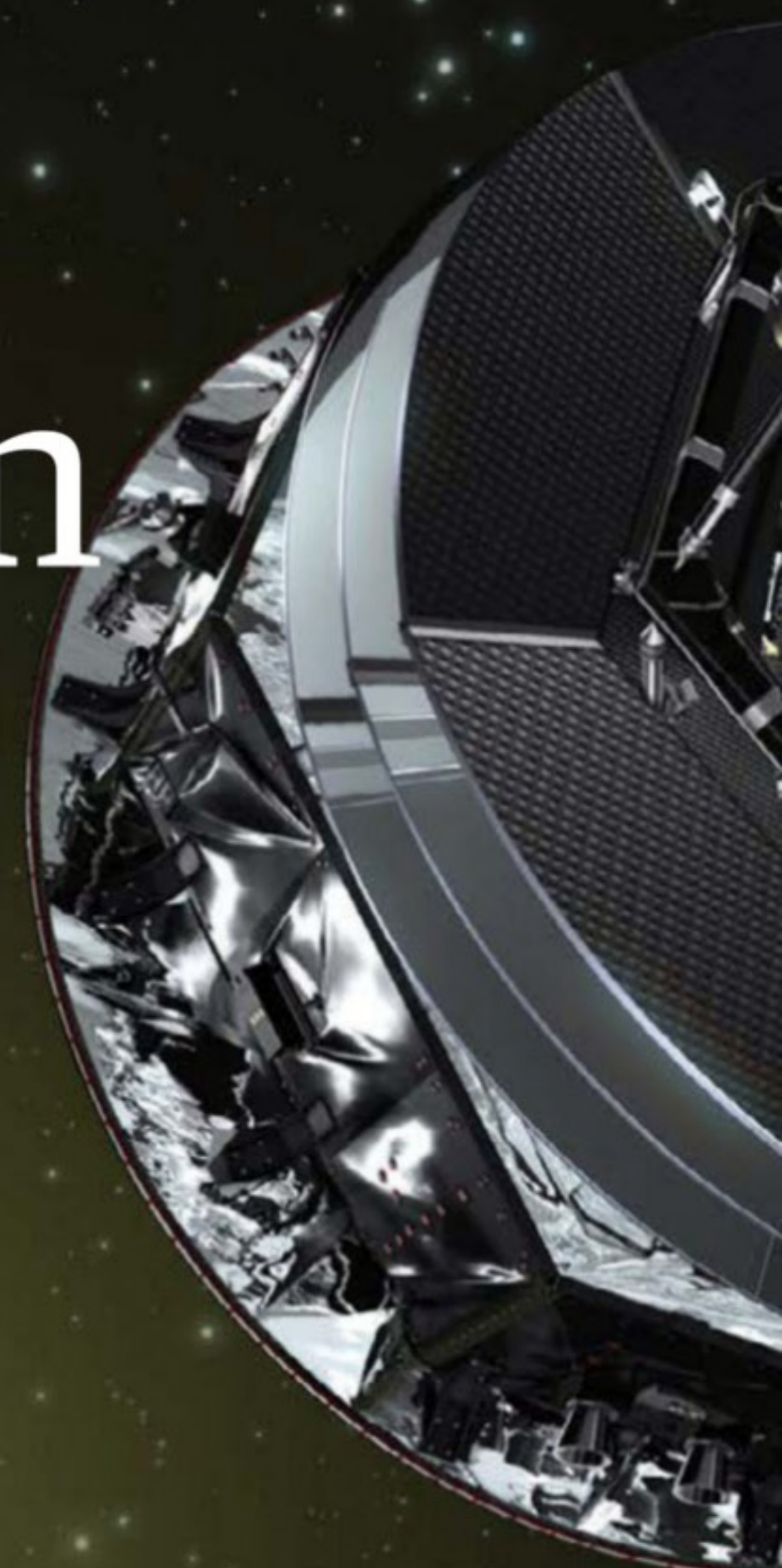
as the cosmic microwave background (CMB), this ancient light was the target of Planck's final mission from 2009 to 2013 and the results have radically altered how we view the timeline of the universe's early phases.

These readings gathered from this 'energy fossil' have also enabled scientists to determine the period in which stars first ignited, and how the CMB was affected on its way through the universe. A key part of this is understanding the process of polarisation. Light is polarised when it vibrates in a preferred direction, something that's usually determined by photons - particles of light - bouncing off one another. It's this process that drives the CMB and it's helping us understand how the contents of each galaxy were formed.

"The polarisation of the CMB also shows minuscule fluctuations from one place to another across the sky: like the temperature fluctuations, these reflect the state of the cosmos at the time when light and matter parted company," says François Bouchet of the Institut d'Astrophysique de Paris, France. "This provides a powerful tool to estimate parameters such as the age of the universe, its rate of expansion and its essential composition of normal matter, dark matter and dark energy."

With this new information, we have a clearer picture of what happened between the Big Bang and the first stars. As these stars came to life the light interacted with gas, the atoms began to revert to their constituent states, a period of time known as the 'epoch of reionisation'. ■

According to the report, the process of reionisation came to end around 900 million years after the Big Bang



Much like the Cassini spacecraft visiting Saturn's moon Titan, the Europa Clipper aims to study its target using a long-loop orbit

Clipper mission to seek life on Europa

In the wake of potential new funding, a new probe could bring us closer to Jupiter's icy moon

With US president Barack Obama's plan to boost NASA funding by \$519 million (£338 million) now one step closer to reality, many of the space agency's proposed programmes are gearing up for the possibility of seeing their visions realised. One such project

hoping to get its time in the Sun, the Europa Clipper mission, aims to send a probe all the way to one of Jupiter's most prominent moons in the hope of studying its icy topography.

In response to the news of the agency's increased funding (especially

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"This provides a powerful tool to estimate in a new and independent way parameters such as the age of the universe"

for new projects), JPL (Jet Propulsion Laboratory) pre-project scientist Robert Pappalardo commented that many goal concepts have possibly been too small, too vast or usually too expensive, though, "we trust we have now found one that is usually right." He added, "We call this judgement a Europa Clipper."

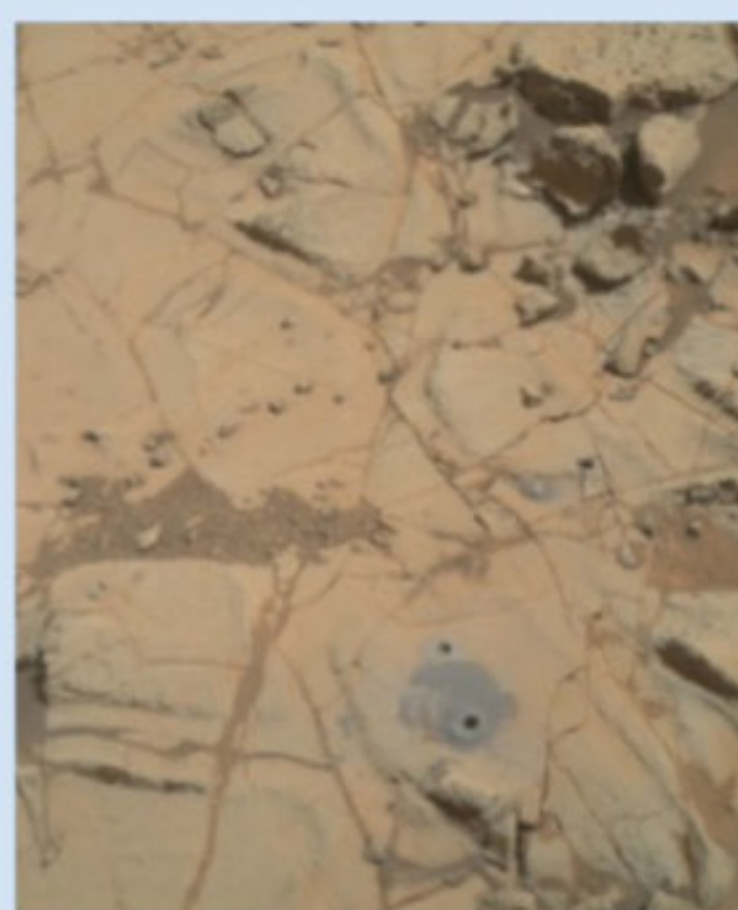
If successful in its goals, the Europa Clipper programme will conduct a mission similar to that of the Cassini spacecraft that has been providing invaluable information on Saturn's moon, Titan. Previous flybys of Europa have revealed a subsurface

ocean beneath its icy crust, a body of water that scientists believe could be the kind of environment that is ideal for supporting life.

Previous proposals to visit Europa have all struggled to get past the drawing board. Most notable among these was the European Space Agency's JUICE (JUperiter ICy moons Explorer) mission, which aimed to visit all four of Jupiter's Galilean satellites (fiery Io, icy Europa, giant Ganymede and the cratered Callisto). However, it failed to get past the planning stage due to the spiralling costs involved. ●

"Previous flybys of Europa have revealed a subsurface ocean that could well be ideal for supporting life"

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The new drilling technique has been designed to avoid damaging tested areas

Martian tests hint at ancient acidic waters

New samples taken by NASA's Curiosity rover have shed new light on the composition of Mars's long-lost bodies of water, thanks in no small part to a new low-percussion drilling technique. Based at the foot of Mount Sharp, Curiosity has been taking readings for almost six months from a specific rocky location codenamed 'Mojave 2'.

Recent tests suggest the waters of Mars were far more acidic than first thought, with large amounts of jarosite, an oxidised mineral that's known to form in highly acidic and humid conditions. Jarosite decomposes in such a setting, so the considerable presence of unaltered specimens suggests a geological shift occurred that rapidly ushered in a dryer, less acidic environment.

"Our initial assessment of the newest sample indicates that it has much more jarosite than Confidence Hills," said CheMin deputy principal investigator David Vaniman, of the Planetary Science Institute, Tucson, Arizona. Confidence Hills is a nearby plain of flat rock that Curiosity has already conducted tests on, with the difference in acidity suggesting that 'Mojave 2' formed in different conditions or was soaked with jarosite-rich water at a later point. ●



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Soil moisture satellite takes flight

NASA launched a satellite in February to detect the density and spread of moisture in the Earth's soil. The SMAP mission aims to study the way water, energy and carbon cycles drive the ecosystems of our home.

Two dying stars found at heart of nebula

While studying the nebula Henize 2-428, astronomers have discovered the answer to its odd shape and formation - a pair of decaying white dwarfs that are locked on a fatal journey and destined to collide in 700 million years.

Obama to boost NASA funding

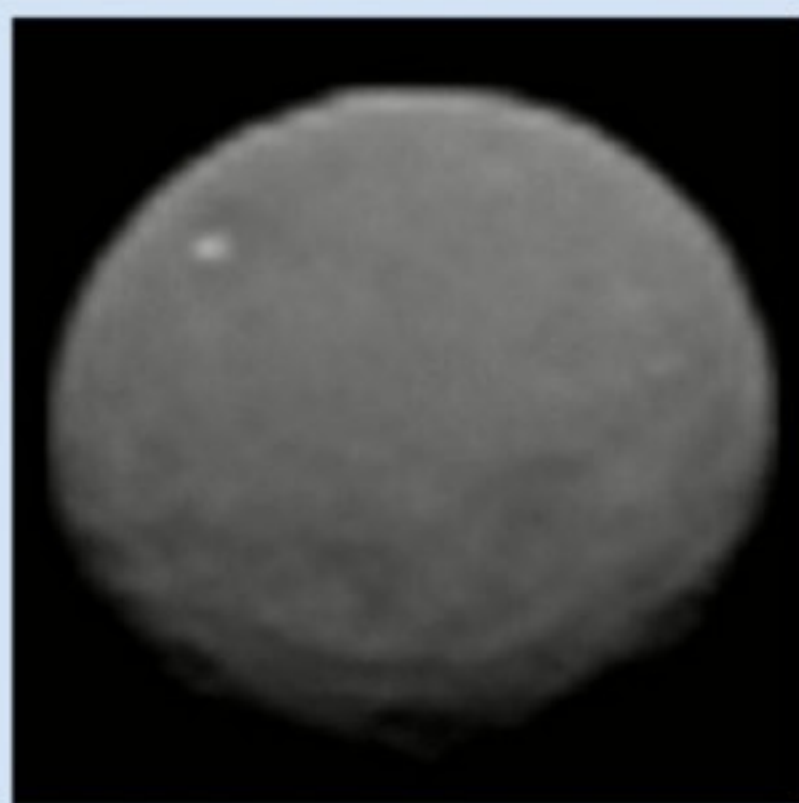
US president Barack Obama has requested a cool \$18.5 billion from Congress to help galvanise the country's space programmes. If approved, however, the new budget will force the long-standing Mars rover Opportunity programme to shut down.

Microsoft/NASA team-up looks to Mars

NASA and Microsoft are developing new software that will enable scientists to work virtually on the Red Planet. The OnSight software will construct Martian plains using a combination of data captured by the Curiosity rover and 3D simulation programs.

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The Dawn spacecraft is due to enter orbit around the dwarf planet Ceres on 6 March, so watch this space for more fascinating snaps

Unknown dwarf planet revealed

New images beamed back from the Dawn spacecraft have helped NASA scientists re-create the clearest image of the dwarf planet Ceres to date. Located in the asteroid belt between Jupiter and Mars, Ceres is the largest planet of its class in our inner Solar System and its unique characteristics have fascinated astronomers for centuries.

There's always been a concern that previous attempts to capture Ceres in greater clarity, including a series of snaps by the Hubble Telescope in 2003, only provided an incomplete picture. The new shots are also shedding a fascinating new light on Ceres' glacial topography. "We are already seeing areas and details on Ceres popping out that had not been seen before. For instance, there are several dark features in the southern hemisphere that might be craters within a region that is darker overall," said Carol Raymond, deputy principal investigator of the Dawn mission at JPL. "Data from this mission will revolutionise our understanding of this unique body. Ceres is showing us tantalising features that are whetting our appetite for the detailed exploration to come." ■

"We're seeing areas on Ceres that hadn't been seen before"

Mars crater mystery solved

New ESA data and images reveals the intriguing history of one of Mars' most interesting regions

While NASA's Curiosity rover busies itself hundreds of miles away in the Gale Crater, the European Space Agency's Mars Express has turned its attention to another fascinating Mars landmark, the Nili Fossae craters. The orbiter, which has been studying the Red Planet for a decade, beamed back a series of shots that reveal a glimpse into the region's history.

One part of the crater, the Isidis impact basin, is believed to have been created by subsidence and through formation, caused by a flood of basaltic lava. Scientists also believe

that many of the region's 'sapping valleys' were caused by percolating hydrothermal fluids, a mixture of ice and water that were superheated by the impact that originally formed these craters. The collision would have caused an explosion of steam that would have either weakened the subsurface causing it to collapse, or blown it away entirely.

Scans of the region's undulating topography also revealed an interesting diversity of minerals, including phyllosilicates (clays), carbonates and opaline silica (metal

oxides). Such an unusual concoction of minerals has attracted the attention of scientists, because such a diverse history suggests Nili Fossae has played host to considerable geological and tectonic forces.

This isn't the first time Nili Fossae has been the subject of scrutiny. Large quantities of methane gas were detected in the Red Planet's atmosphere back in 2009, leading NASA and ESA scientists to wonder whether the gas was the product of a geological process or the result of biological decomposition. ■

Nili Fossae was actually on the list of potential study sites for the Curiosity rover, but was ultimately passed up in favour of the Gale Crater

New Horizons closing in on dwarf planet Pluto

With less than four months to go before its planned flyby, the spacecraft captures a glimpse of the second-largest dwarf planet in our Solar System

The largest pinprick of light is Pluto, while the smaller one is one of its moons, Charon



After almost eight years of space travel, NASA's New Horizons is months away from the crux of its mission: the study of Pluto. As the probe enters its final approach, it marked the 109th birthday of the man who discovered the dwarf planet, Clyde Tombaugh, with a series of new images. New Horizons was around 203 million kilometres (126 million miles) away when the shots were taken, using its on-board telescopic Long-Range Reconnaissance Imager (LORRI) to capture Pluto in all its distant glory.

"Pluto is finally becoming more than just a pinpoint of light," said Hal Weaver, New Horizons project scientist at the Johns Hopkins University

Applied Physics Laboratory. "LORRI has now resolved Pluto, and the dwarf planet will continue to grow larger in the images as New Horizons spacecraft hurtles toward its targets. The new LORRI images also demonstrate that the camera's performance is unchanged since it was launched more than nine years ago."

New Horizons will continue to take hundreds of shots of Pluto as the probe draws ever nearer, enabling NASA scientists to build the most comprehensive study of the icy dwarf planet. The probe is estimated to arrive at Pluto around the end of June, with its first planned flyby pencilled in for 14 July. ■

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Journey to MARS

By the 2040s, humans will have walked on Mars and nothing is going to stop that. Don't believe us? **All About Space** runs through the incredible developments taking place that are making this dream a reality

Written by Jonathan O'Callaghan

We have reached the point of no return. Already, NASA have invested billions of dollars: the spacecraft that will take the astronauts into space and return to Earth has been built, tested and flown. The rocket that will carry the spacecraft is halfway to completion, the heat shield that will take humans to the surface has been demonstrated, and the spacesuit in which astronauts will take the first steps on Mars has been created. There is no doubt that this time, it is real. Mankind will set foot on Mars within the next four decades and there is almost nothing that will stop that from happening.

Of course, there are other space agencies that are beginning to get involved, too. The ESA has already committed to helping NASA, while others like Russia may follow suit after the ISS is decommissioned in 2028 at the latest. Several nations have recently undertaken unmanned missions to Mars, or plan to in the future, which will provide invaluable data for the eventual manned mission. And there is of course the rise of private space ventures, not least of all Elon Musk's SpaceX, which has already stated its ambition to land humans on the Red Planet.

When the Orion spacecraft lifted off on 5 December 2014, it wasn't just a demonstration of how NASA is getting back into human spaceflight.

This was the first step towards landing humans on Mars, the first of six pieces of a puzzle that will be necessary for humanity, in two or three decades depending on the progress that is made, to hear the first words spoken from the Red Planet, whatever they may be.

These six puzzle pieces were laid out by Boeing in a recent presentation, and have been broadly agreed as the best way to get to Mars. They are half a dozen technologies that will make a mission possible.

The first is a rocket that will lift the other five pieces of the puzzle into orbit, perhaps through multiple launches. For NASA that's the Space Launch System, which will make its maiden flight in 2019, while SpaceX will also throw its hat into the ring this year with the less powerful (but nonetheless impressive) Falcon Heavy.

Next is a vehicle that can take humans off Earth and return them at the completion of the mission: NASA's Orion, or SpaceX's Dragon. A new type of heat shield will also be required to successfully take humans through the atmosphere of Mars in a spacecraft designed to land, and slow them to a sufficient speed that they can



BIO

Patrick Troutman

Exploration systems analysis lead Patrick Troutman works at NASA's Langley Research Center, and is involved in many projects that look to the future. Aside from studying missions to Mars, he also researches grandiose plans such as space settlements.

Getting to Mars

The systems and spacecraft that will be used to help humans reach the Red Planet

Spacecraft adapter

At the bottom of the Orion spacecraft is an adapter that will attach it to the Space Launch System rocket that will take it to orbit.

Crew Module

At launch, a crew of four will sit here in the Crew Module as they are taken into space. At the conclusion of the Mars mission, they will also travel back to Earth in this module.

Launch Abort System

In case of an error during launch, this escape system – fitted with small retro rockets – will propel the Orion spacecraft and its crew to safety, away from the rocket.

Service Module

Built by the European Space Agency, the Service Module will provide the propulsion, electrical power and storage required by the crew to survive and move in space.

Purpose

The configuration of the Orion spacecraft seen here will likely be used by astronauts on other missions, such as to an asteroid. For a mission to Mars, other components will be needed.

Space Launch System (SLS)

Weight: 2.95 million kg (6.5 million lb)

Height: 117m (384ft)

Cargo: 130,000kg (286,600lb) to orbit

Thrust: 4.2 million kg (9.2 million lb)

Engine: J-2X

Fuel: Liquid oxygen and liquid hydrogen

Cost per launch (estimated): £330 million (\$500 million)

Maiden flight: 2018

The Orion spacecraft

Orion will be the vehicle that takes a human crew of four into Earth orbit, and ultimately returns them to Earth after they have completed their mission to Mars.

It is a cornerstone of any successful mission to Mars, similar to the way the Apollo Command Module was a necessity for humans returning from the Apollo missions in the Sixties and Seventies. The entire Orion vehicle will include a Launch Abort System, a Crew Module and a Service Module.

After an unmanned test flight in December, its next flight is scheduled for 2018 (an unmanned flight around the Moon) before its first crewed flight as early as 2021.

surface. For now this is the Low-Density Supersonic Decelerator (LDSD), an inflatable doughnut-shaped heat shield that NASA has already tested in Earth's atmosphere, in 2014.

The last three pieces, admittedly, are among the hardest. A transit habitat will be needed for astronauts to live in on their nine-month mission to Mars. A 'tug' spacecraft will be needed to propel the astronauts to Mars. And an ascent vehicle will be needed to get them off the surface. But it will not be long before

these are put into development in the coming years.

However, you'd be forgiven for being sceptical up until now, because these promises have been made countless times before. In particular, with the final Apollo mission in 1972, most had been of the belief that the next step would have been to Mars. In the first issue of **All About Space**, Jack Schmitt, Lunar Module pilot for the Apollo 17 mission and the last of just 12 astronauts to set foot on the Moon, told us it was a major disappointment that Mars was not the

ultimate destination at the time.

Back then, NASA was developing a nuclear-powered rocket known as NERVA (Nuclear Engine for Rocket Vehicle Application), which was considered as a suitable engine to take humans to Mars and bring them back. Sadly, in 1972 it was cancelled, in favour of developing the Space Shuttle.

In the decades that followed, several loose concepts would be drawn up by the US, Russia and even Europe, but ultimately all were dropped amid mounting budget costs and technological concerns. But now a mission to Mars is very much back on the agenda, following the launch of Orion, and the development of the Space Launch System rocket. It will not be without its challenges, but we are moving in the right direction.

"There are so many hard things about getting to Mars," Patrick Troutman, exploration systems analysis

"The long-term goal of humans going to Mars is simply to establish an avenue for humanity's survival"

Patrick Troutman, NASA exploration systems analysis lead

Fast fact

The lifting capability of the Space Launch System Block II will be the equivalent of taking 22 fully grown elephants to orbit.

Cargo

The ISS-bound Dragon V2 will be capable of carrying 3,310kg (7,300lb) of cargo to the ISS, the equivalent of three average cars. For missions to Mars, carrying cargo to the surface will be essential.

Falcon Heavy

Weight: 1.46 million kg (3.2 million lb)

Height: 68.4m (224ft)

Cargo: 53,000kg (117,000lb) to orbit

Thrust: 1.8 million kg (4 million lb)

Engine: Merlin 1D

Fuel: Liquid oxygen and kerosene

Cost per launch (estimated): £55 million (\$85 million)

Maiden flight: 2015



Crew

The Dragon V2 will be capable of taking seven humans into low Earth orbit. It's likely the Mars version of the Dragon will carry less, in order to make landing on the Red Planet easier.

Landing

SpaceX's goal is for its Dragon spacecraft to be able to land "anywhere in the world". Eight thrusters will be used to land the Dragon V2 on Earth, and a similar number could help it land on Mars.

Flight

There will be 18 thrusters on the Dragon to allow it to manoeuvre in space, which will be important for undocking or docking to a larger Mars-bound "mothership".

Heat shield

SpaceX uses an advanced heat shield known as PICA-X on its existing unmanned Dragon capsule, which it says can also "withstand the much higher heat of a Moon or Mars velocity re-entry".

SpaceX's Mars Dragon

SpaceX's plans to land humans on Mars include an upgrade on its existing unmanned Dragon spacecraft into a manned craft.

This next version will be known as V2, and will be used to take astronauts into low Earth orbit. It will carry a crew of seven, and will be used to transport astronauts to the ISS. Testing will begin this year, after the company revealed a full-scale mock-up in 2014. SpaceX has also tentatively hinted at an unmanned Mars vehicle known as Red Dragon that will return samples from the Red Planet.

Combined, these two concepts could lead to a manned Mars vehicle - perhaps called Dragon V3 or even V4 - that could be used in tandem with a NASA mission to land humans on Mars.

lead at the NASA Langley Research Center, tells **All About Space**.

"Broadly, there is surviving the mission, enabling the mission and paying for the mission. And I think that surviving the mission is the hardest, because it drives the other two. There's no sense in sending people to Mars if they cannot survive it. There are so many critical mission events that must succeed, and when you combine them all together the odds are never as good as the levels of safety we are willing to embrace in our personal life."

Troutman's belief, though, is that the first missions to Mars should not be, as he puts it, expensive "flags and footprints missions" like the Apollo programme, with "perhaps another long pause in humans venturing out beyond low Earth orbit."

What he wants to see is investment in new levels of autonomy, reliability and resource utilisation

that will allow humans to make prolonged stays on the Red Planet, allowing us to "sustainably and continuously explore".

It is an opinion shared by many other experts in his field, most notably Elon Musk, CEO of SpaceX. Musk has made no secret of his desire to also land humans on the Red Planet and, like NASA, SpaceX is also busy building some of the infrastructure that will be necessary for such a mission.

Towards the middle of this year it is expected that the Falcon Heavy will take flight for the first time, a smaller rocket than the Space Launch System but one that will have the lifting capability to make a mission to Mars plausible. Musk has also promised that later this year he will reveal details on the secretive Mars Colonial Transporter, a vehicle many believe will be SpaceX's answer to getting humans to the surface of Mars.

It's more than likely that when all the pieces fall into place, this will not be a mission NASA and SpaceX attempt alone. "Something like a human Mars mission will be international," says Troutman. "There may be some nations that contribute more or less, but in the end it's the people of Earth extending their reach into the Solar System."

That is something that Mike Raftery, director of ISS Utilization and Exploration at Boeing, which is building part of the SLS for NASA, agrees with.

"We have a technology path to Mars, but it will require sustained commitment over more than a decade," he tells **All About Space**. "I would say that maintaining stable, year-over-year funding is the greatest challenge of getting humans to Mars. That would be one of the benefits of international cooperation, similar to what we did with the International Space Station."

He continues: "Human exploration of Mars will require substantial and long-term investments of talent, capabilities, and financial resources to create a complex yet reliable transportation system. NASA is uniquely suited to lead the way, but real progress will require international cooperation and innovation, both of governments and industries."

That, in itself raises an interesting point. By 2028 at the latest, the ISS project will come to an end, owing not only to limited uses for the space station beyond that date but also, its components will be reaching the end of their reasonable operational lifetime. This will leave NASA with £2.6 billion (\$4 billion) or so of spare funding that will be repurposed for other means and it's more than likely some of this will go towards the deep space exploration programme. Other nations too, will have a surplus exploration budget to spend - and they will very likely get involved with this new international endeavour.

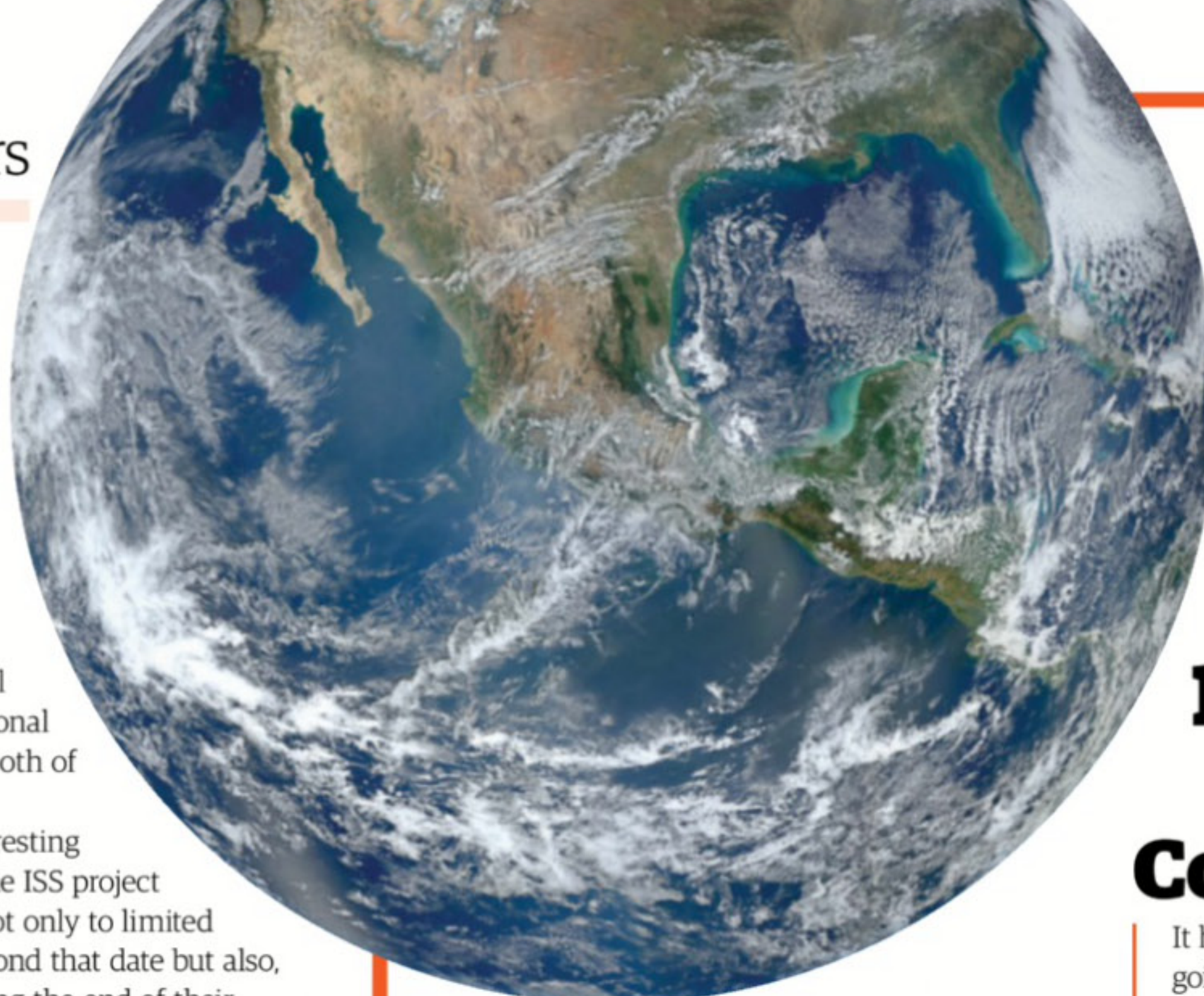
In December 2012, ESA agreed with NASA that it would build the Service Module for the Orion spacecraft's unmanned journey to lunar orbit in 2017. In 2018, meanwhile, it will launch its ExoMars rover towards the Red Planet. And it has also been very busy drawing up concepts for lunar missions. Whatever shape the Mars mission takes, ESA will certainly be involved.

On the topic of returning to the Moon, there have been rumblings as to whether NASA would be better suited returning to the lunar surface before attempting to go to Mars. In June 2014, the National Research Council (NRC) in the US advised that NASA should consider sending humans to lunar orbit before it embarked on a Mars mission or it would "invite failure". In its report analysing NASA's plans for Mars, it suggested that the agency's current plans were somewhat risky.

Those plans involve robotically capturing an asteroid at the start of the 2020s, then repositioning it in lunar orbit. Astronauts would then be sent to the asteroid to analyse it, return samples and test technologies intended for the Mars mission. They readily admit that the jump to a Mars mission after that would be difficult - but there is no reason to think it couldn't be done.

"We know there are solvable challenges for human missions to Mars, including getting there, landing,

"We need to know if astronauts can cope with being in a microgravity environment for about two years"



The challenges of a Mars mission

Cost

It has often been said that the biggest challenge of going to Mars is the cost. An expert panel recently estimated the cost of a 20-year programme ranges from £52 to £65 billion (\$80 to \$100 billion). Surely one nation could not undertake that alone?

Solution:

Actually, it's not all bad. Those estimates work out to about £2.6 billion (\$4 billion) to £3.2 billion (\$5 billion) per year. NASA already spends £2.6 billion (\$4 billion) a year on its human exploration programmes, and a similar amount operating the ISS, which will be decommissioned by 2028 at the latest. If managed responsibly, the cost of getting to Mars might not be insurmountable - especially if the mission is an international endeavour.



Fuel

The larger a spacecraft is, the more fuel it needs to travel through space. Keeping the fuel requirements low on any Mars mission, particularly the amount of fuel that needs to be carried, will be essential.

Solution:

For the journey to Mars, it may be possible to use alternate sources of fuel to chemical engines - such as solar electric power, or ion propulsion. On Mars, it may even be possible to produce fuel from Martian water and the carbon dioxide atmosphere.

Contamination

One of the greatest fears of any mission to another world is that of contaminating it, and seeding it with life. This could create false readings in future when searching for signs of extraterrestrial life.

Solution:

Every piece of equipment that travels to Mars will have to be extensively sterilised to ensure it does not carry any Earth-based bacteria or microbes. But with present-day technology, there is not currently an adequate method to prevent similar contamination from humans.

Food

When astronauts land on Mars, they will want to be able to carry as few supplies as possible in order to maximise their payload capacity. But with only a limited amount of cargo space available, how will they stay fed on the surface?

Solution:

Recent experiments have shown that it should be possible to grow crops and plants on Mars, perhaps in specially designed greenhouses. It may also be possible to actually use 3D printers to create different types of food.

Equipment failure

The astronauts have landed safely on Mars and are several days into their mission when a life support system necessary for their survival fails. Without means of getting a replacement from Earth, how will they survive on the Red Planet?

Solution:

Fear not, because NASA already has the answer to this question - and it is testing it right now on the ISS. 3D printers will be used on a Mars mission to print any tools or parts needed for the astronauts' survival on the Red Planet.



Low gravity/ Microgravity

Human bones deteriorate in the microgravity environment of space, and they will also weaken on Mars, where gravity is just 38 per cent that of Earth's.

Solution:

For travel to Mars, it may be necessary to rotate the astronauts' habitat to provide artificial gravity. On Mars, regular exercise will need to be taken to keep bones strong.

Fluid shift

Without Earth's gravity, blood is not circulated properly to the lower parts of the body, which can cause a puffy face and shrink astronauts' legs.

Muscles

In reduced gravity certain muscles, particularly in the arms and legs, can weaken as they are used less often, affecting balance, posture and strength.

Vision

Weightlessness increases the amount of fluid in the upper part of the body, increasing pressure on the eyes and causing eyesight problems.

Loss of balance

The inner ear is unable to maintain balance in a weightless environment as it relies on gravity, which can cause a loss of balance and space sickness in astronauts.

Kidneys

Bone loss can cause calcium to build-up in the kidneys, leading to kidney stones.

Bone loss

Reduced gravity causes the human body to excrete calcium and phosphorous in its waste, causing rapid bone loss.

Smaller heart

The heart doesn't have to work as hard in microgravity, which could weaken it over time and even cause it to shrink in size.

Psychological effects

How long can humans stay cooped up in a small environment before they suffer debilitating psychological effects? Fears of isolation, arguments among the crew and even boredom have all been cited as possible problems facing a future mission to Mars.

Solution:

From 3 June 2010 to 4 November 2011, six humans spent 520 days in a mock-up spacecraft on Earth as part of the Mars 500 mission, to simulate a mission to and from Mars. The project was a huge success, with no serious psychological effects, proving that it might not be so tough on the human mind when the actual mission to Mars takes place.

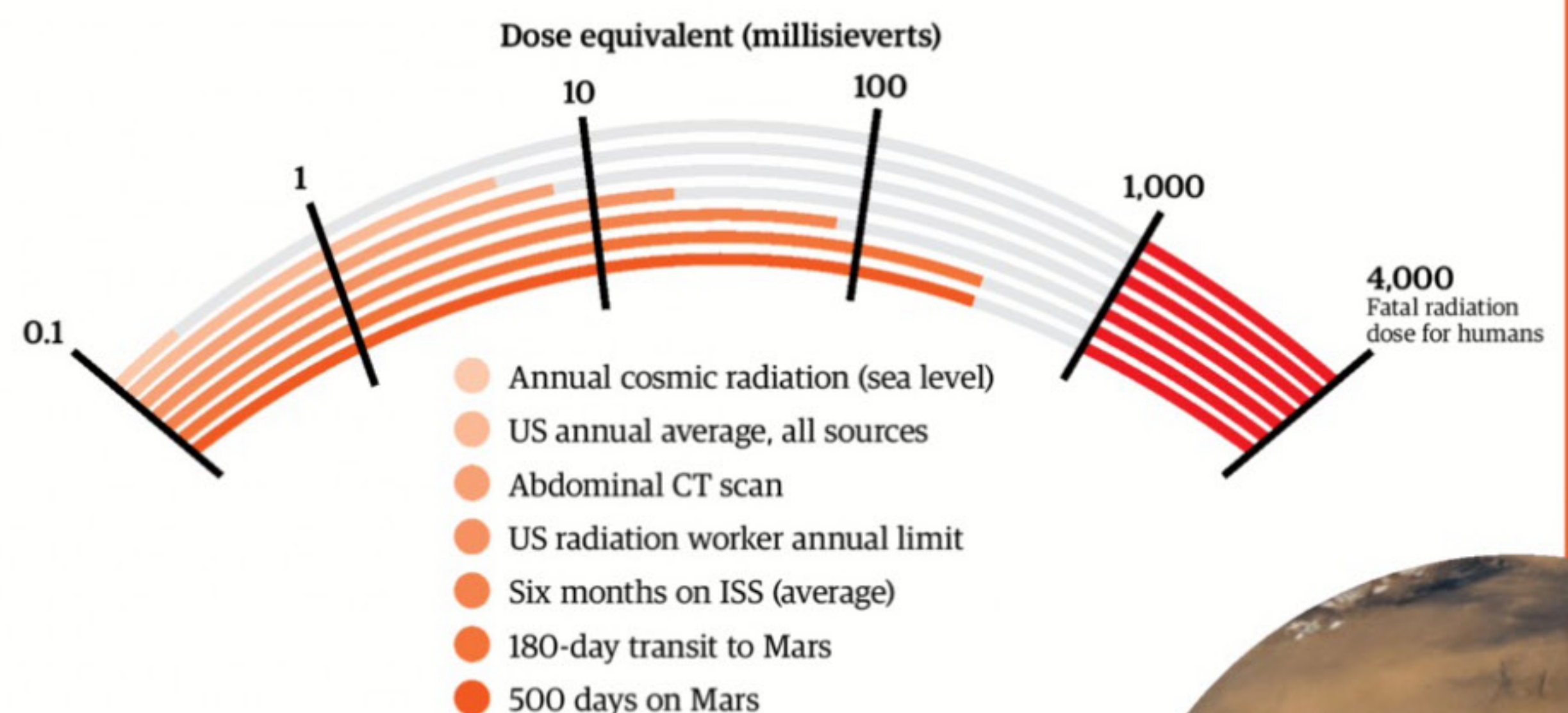


Radiation

The exact radiation risks of Mars missions are not fully understood, but it's widely agreed that without the protection of Earth's atmosphere, the increased exposure to cosmic rays in space and on Mars could be harmful to astronauts.

Solution:

It will be necessary to shield spacecrafts from radiation, possibly by filling their walls with water. A radiation-safe room for astronauts may also be needed when radiation levels are expected to increase.



Why Mars?

Based on data from rovers and spacecraft, we now know that Mars once had water on its surface, although what became of it remains a mystery. Water could indicate that the planet once hosted life, or still does.

It's been said that a human could do in a week what the rovers have done in

their lifetime, so getting humans to Mars could enable quicker and more extensive science. It also provides a stepping stone to human settlements on other planets, which might be important for the survival of our species if Earth faces a global catastrophe.





The road to Mars

The missions that will pave the way for human exploration of Mars

05 ExoMars

Category: Robotic
Mission type: Rover
Launch: 2018

In 2018 the European Space Agency plans to launch its ExoMars rover, which will land on Mars in 2019. Aside from searching for signs of past and present life, one of its key goals will be to identify any hazards for future manned missions.

06 Mars 2020

Category: Robotic
Mission type: Rover
Launch: 2020

The Mars 2020 mission will be a successor to the Curiosity rover, with the primary goal of finding out if Mars was once - or still is - habitable. The results from this could help decide the goals of a subsequent manned mission to the Red Planet.

07 Rosetta

Category: Robotic
Mission type: Probe
Launch: 2004

On 12 November 2014 the Rosetta spacecraft's Philae lander successfully landed on comet 67P/Churyumov-Gerasimenko, chalking up another celestial body our spacecraft have landed on and paving the way to grander destinations.

08 Telerobotics

Category: Human
Mission type: Rover
Launch: 2015

A proposal for exploring the surface of Mars, before humans travel there, is to place a crew in orbit and have them operate rovers on Mars' surface. This would alleviate the time delay of missions, allowing for quicker exploration overall.

living, working and safely returning," a spokesperson for NASA tells **All About Space**.

But they cite their current work on the ISS as being integral to a Mars mission. In March of this year, NASA astronaut Scott Kelly will embark on the first year-long mission on the ISS, along with Russian cosmonaut Mikhail Kornienko. The mission will provide key scientific data on how the human body copes with prolonged spaceflight - and this is just

one of many such Mars preparation missions that NASA has planned.

The journey to Mars will take seven or eight months, similar to unmanned missions to Mars, owing not to limited forms of propulsion but simply because of the way the planets orbit. Missions to Mars launch about every two years when a window opens that allows the shortest route possible between Earth and the Red Planet, when they are closest in

their orbits. It's inconceivable to think NASA and others won't make use of this window.

Using this timescale, the astronauts will be required to stay on Mars for a year until the planets align in such a way again that they can return. And that is an important point to make - NASA has been adamant all along that the astronauts will return to Earth once their mission expires and not be left there to live out the rest of their days.

This is why studies of prolonged human spaceflight are so important - we need to know if astronauts can cope with being in a microgravity environment for about two years, and how harmful the effects of radiation will be.

On the surface, the astronauts will likely have multiple habitats, perhaps with greenhouses to grow crops, while spacesuits - evolved versions of the Z2

"We send people so that we can understand what it will eventually take to guarantee our survival"

Michael Raftery, director of ISS Utilization and Exploration at Boeing



01 LDSD

Category: Cargo

Mission type: Lander

Launch: 2014

To land large payloads, it will be necessary to pass through Mars' atmosphere and slow sufficiently before touching down. NASA thinks the answer could be the Low-Density Supersonic Decelerator, an inflatable 'doughnut' which it tested last year.

02 Lunar cargo lander

Category: Cargo

Mission type: Spacecraft

Launch: 2020s

In order for humans to survive on Mars, it is likely cargo will need to be transported separately. This will need to be proved first, and the testing for this can be done on the Moon alongside a manned mission, due within the coming decade.

03 Commercial cargo

Category: Cargo

Mission type: Spacecraft

Launch: 2012

When SpaceX's Dragon spacecraft docked with the ISS for the first time on 25 May 2012, it ushered in a new age of private space exploration. Such companies could prove invaluable in helping to get cargo off the Earth and onto Mars.

04 Heavy-lift vehicles

Category: Cargo

Mission type: Rocket

Launch: 2015

NASA and SpaceX are building heavy-lift rockets that will be essential for a Mars mission, while Russia and ESA are developing new rockets of their own. Together, they will provide the means of launching equipment, humans and spacecraft for a manned Mars mission.

09 ISS

Category: Human

Mission type: Spacecraft

Launch: 1998

The ISS is a global project between the US, Russia, Japan, Europe and Canada. It's proof the governments of the world are willing and able to work together in space exploration. It also provides a testing ground for many aspects of human spaceflight.

10 Asteroid Redirect Mission

Category: Human

Mission type: Spacecraft

Launch: Mid-2020s

In the 2020s, NASA will use an unmanned spacecraft to move a whole or part of an asteroid, into lunar orbit. Here, humans in the Orion spacecraft, launched on a Space Launch System (SLS) rocket, will explore it, providing valuable experience for them.

11 Crewed lunar lander

Category: Human

Mission type: Spacecraft

Launch: 2020s

Several proposals for getting to Mars call for humans to first return to the Moon. If this is to be done, modern human-rated lunar landers will have to be built, which can land crew and cargo on the surface before lifting off and returning to orbit, or Earth.

12 Orion

Category: Human

Mission type: Spacecraft

Launch: 2014

Orion, the spacecraft that will carry humans off and back to Earth again, completed its maiden flight last year. Its first crewed flight will be in 2021, ahead of a later mission to an asteroid (Asteroid Redirect Mission) and ultimately, Mars.

currently in development - will enable them to walk on the surface and perform key experiments.

As Troutman points out, though, journeying to Mars is not and should not solely be about the science that can be learned. "The long-term goal of humans going to Mars is simply to establish an avenue for humanity's survival," he says.

"Establishment of more than one biosphere for humanity to live in increases our odds of surviving both man-made and natural catastrophes.

"Yes, there is science, commerce, inspiration and technology spin-offs, but they are near-term payoffs that could be accomplished by robotic missions. We send people so that we can understand what it will eventually take to guarantee our survival. Robots can't live for us."

And Raftery adds: "The Apollo space programme

- our pursuit of a Moon landing - fundamentally changed how we live today, improving access to potable water in third-world villages, launching new medicines and medical procedures, and exponentially advancing communications and computing. In so many ways, how we work and play was transformed. Can you imagine what we will learn in seeking to inhabit Mars?"

If money was no object, Troutman says we could launch a rocket every week on missions to the Moon, Mars and selected asteroids. These rockets would be full of robots, building materials and critical space

parts. Of course, money is an object, so progress will be slow - but steady. But despite the fanciful air that sometimes accompanies dreams of missions to Mars, it's important to note that serious progress is now being made.

In four decades, we will know who the first people to set foot on the Red Planet were. Their names will be etched in history. You will be able to come back, read this article, and reminisce on where it all started to take shape. 2015 will be the year when, finally, setting foot on Mars was no longer just a fantasy; it was a reality. ●

Do you think we'll set foot on Mars before 2050?
Let us know on Twitter: **#GethumanstoMars**

Explorer's Guide The Moon

Take a tour of our nearest neighbour and discover a world much stranger than you thought

The Moon's diameter is 27 per cent of Earth's, which is freakishly large. Jupiter's moon Ganymede is larger in absolute terms, but compared to its parent planet it is just a speck, with less than a fiftieth of the diameter. The disproportionate size of the Moon reflects its unusual origins. Most other moons are captured asteroids, or leftover material from the ball of dust and gas that coalesced to form the Solar System. But the Moon is made from the rubble of another planet, called Theia, that collided with Earth around 4.5 billion years ago.

When it was first formed, the Moon may have been ten times closer to Earth than it is today and would have caused tides on Earth several kilometres high. Over billions of years, the gravitational drag of the tides has slowed the Moon's orbit, causing it to spiral outwards from us. Earth's gravity also raises small 'land tides'

on the Moon, stretching it slightly and creating another drag that has synchronised its rotation, so that it always presents the same face to Earth.

The full Moon in the night sky looks flat, rather than darkening at the edges as you'd expect from a 3D sphere. This effect is caused by the unusual properties of the lunar soil, or 'regolith', which reflects more light when the Sun shines at a low angle, than when it is directly overhead. Moon rock is about the colour of a dry road, but a full Moon appears much brighter than that, because all the tiny shadows cast by the regolith disappear when the Sun shines from behind our viewpoint. The regolith can be up to 20 metres (66 feet) deep on the Moon's highlands and in the early days of lunar exploration there were real concerns that spacecraft would simply sink into it.



Sea of Rains

Schroter's Valley

Copernicus crater

How to get there

1. Lift off

The first 200km (124mi) is the hardest. It takes about 23 tons of fuel to propel each ton of payload into orbit, not counting the mass of the empty rocket stages.

3. Transfer burn

To reach the Moon, the spacecraft must fire its engines to accelerate by another 3.2km/s (7,200mph), stretching its circular orbit into a long, thin ellipse.

4. Coast

The transfer burn is timed so that by the time the spacecraft reaches the top of its orbit, the Moon has travelled to the same point in space.

2. Parking orbit

Having accelerated to 7.8km/s (4.8mi/s), the spacecraft makes a couple of orbits around the Earth, a few hundred kilometres up, to check all its systems are working correctly.

5. Landing

Once it gets close enough, the spacecraft fires its engines again to slow down just enough to be captured by the Moon into an orbit, or even more for a direct landing.



How big is the Moon?

The Moon is the fifth largest satellite in the Solar System and the biggest in comparison to its host planet



Luna 2 impact site

Sea of Serenity

Sea of Tranquility

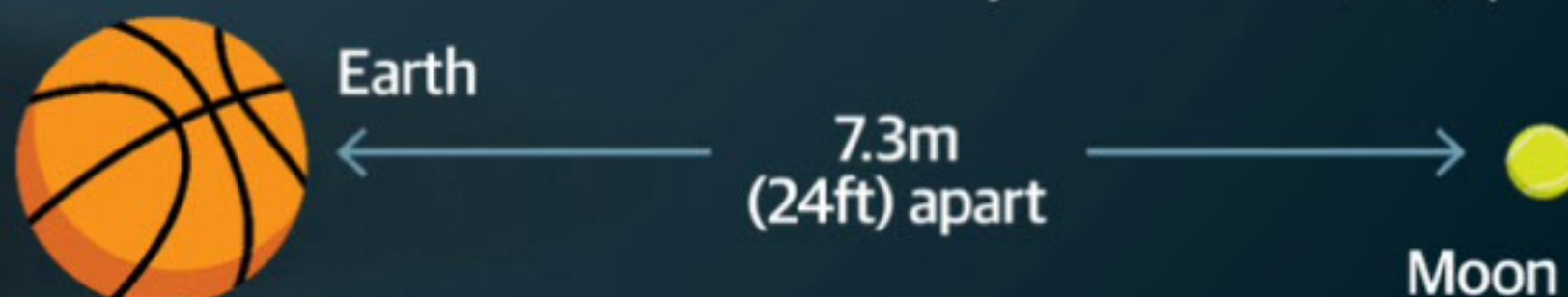
Tycho crater



Moon

How far is the Moon?

The Moon is currently 384,400km (238,855mi) away from Earth but is gradually moving away at a rate of 3.82cm (1.5in) a year. If the Earth was a basketball and the Moon a tennis ball - they would be 7.3m (24ft) apart.



Top sights to see on the Moon

Seen from Earth, the most obvious features on the Moon are the 'maria' or seas. These are vast plains of solidified lava that originally bled for tens of millions of years from the puncture wounds of asteroid impacts. They are darker than the rest of the Moon's crust because of the iron compounds in the basalt minerals. The Moon long ago cooled and set solid all the way through, so it doesn't have tectonic plates to throw up mountain ranges like Earth's. But asteroid impacts can do the same job in a fraction of the time. Large impacts create mountain ridges around their rims, such as the Montes Rook which form a ring 500 kilometres (310 miles) wide around the Mare Orientale. Where an impact crater hasn't been filled in by lava to form a mare, there is also a central

mountain formed where the crust rebounded from the initial impact. Impacts can fling debris out over hundreds of kilometres. These form spokes of lighter asteroid material overlaid on the darker lunar regolith. Tycho crater in the southern hemisphere has rays that extend 1,500 kilometres (930 miles) from its rim.

When the Soviet Union sent Luna 3 to photograph the far side of the Moon for the first time, in 1959, they found it strangely lacking in maria. This is because the crust is thicker on the far side, so asteroid impacts didn't punch all the way through to the magma beneath. Instead the terrain is more irregular, thrust into a jumble of spires by the shockwaves from ancient impacts on the opposite side that travelled through the Moon and burst out

of the surface, like an exit wound. Without water or wind, the landscape is unweathered, so every mountain is sharp and jagged.

As well as mountains and craters, the Moon has twisting features that look like river valleys. Called 'rilles', these may have been caused by lava tubes that cooled and sank into the regolith. Hadley Rille, where Apollo 15 landed, runs along the base of the Apennine mountains. Schroter's Valley is the largest lunar rille. It begins at a crater six kilometres (3.7 miles) wide and meanders for hundreds of kilometres in a strip that is ten kilometres (6.2 miles) wide in places. In fact it's so big that it has another smaller rille formed by a second lava flow, running along it like a river meandering through a glacial valley.

Copernicus crater

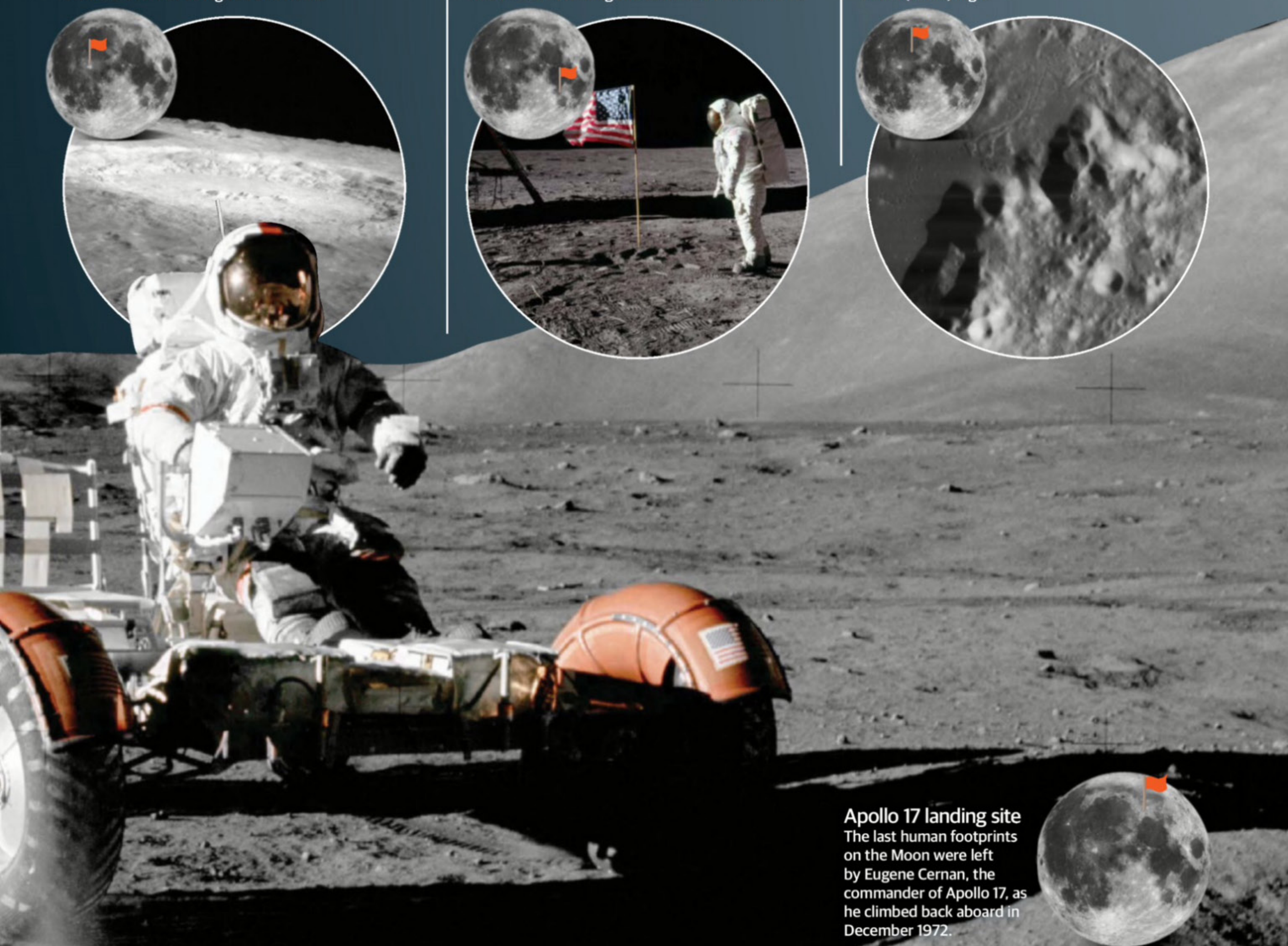
A relatively young crater at 'just' 800 million years old. The mountains in the centre are almost as high as Ben Nevis.

Apollo 11 landing site

Chosen because it was fairly flat, Neil Armstrong nevertheless had to manually pilot 6km (3.7mi) from the intended landing site to avoid a boulder field.

Tallest lunar mountain

Mons Huygens is part of the rim of the vast crater that filled with lava to become the Sea of Rains. It is 5.5km (3.4mi) high.



Apollo 17 landing site

The last human footprints on the Moon were left by Eugene Cernan, the commander of Apollo 17, as he climbed back aboard in December 1972.

The lunar orbit explained

The Moon spins on its axis at the same speed as it rotates around the Earth. This 'tidal locking' means a day on the Moon lasts almost four weeks. As the day/night terminator creeps slowly across the surface, we see a different phase illuminated in the sky each night, from new Moon to full Moon and back again.

The Moon's orbit is oval shaped

Perigee

363,400km/225,800mi (distance when closest to Earth)



Apogee

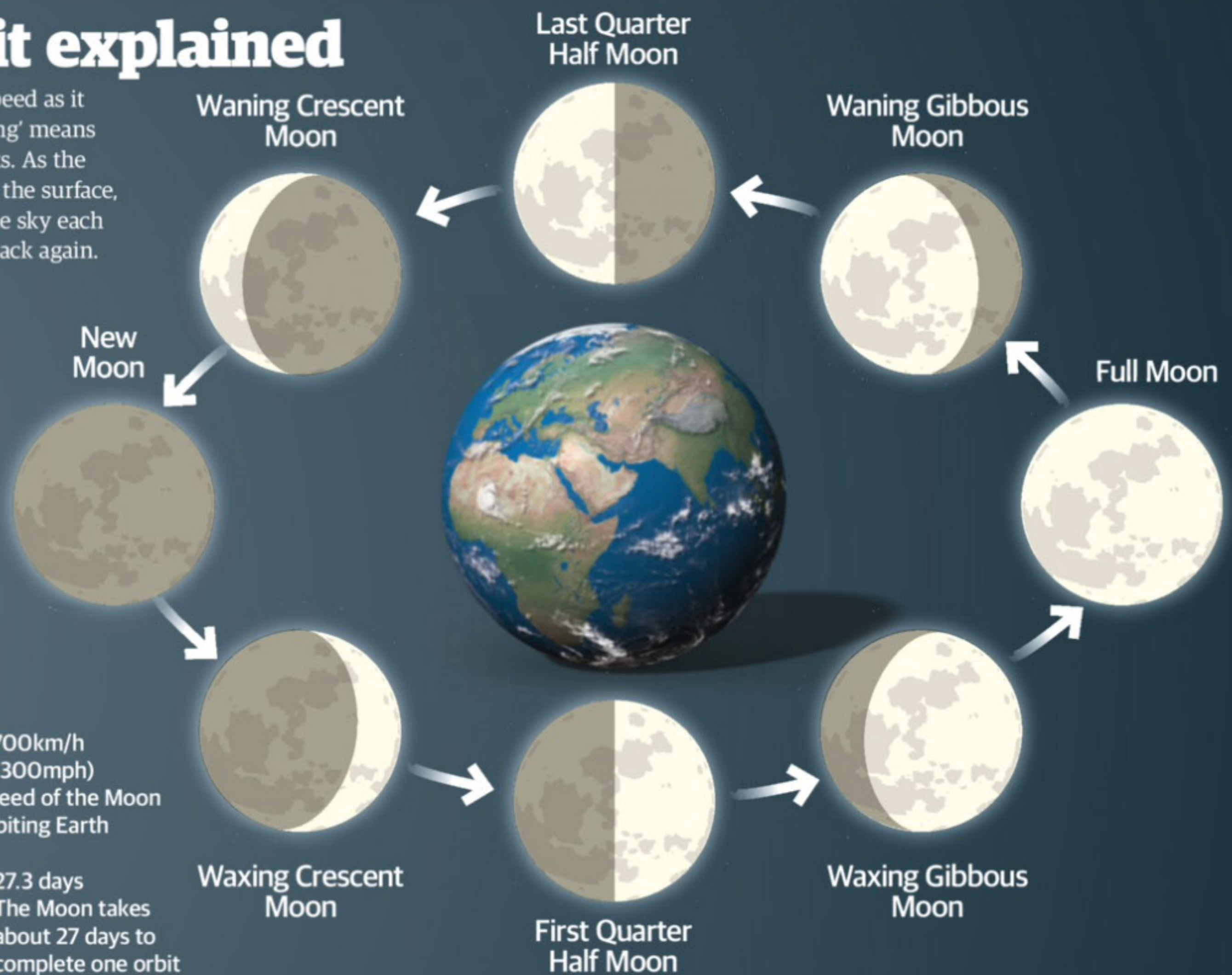
405,500km/252,000mi (distance when farthest to Earth)

16km/h (10mph)
Speed of the Moon's rotation

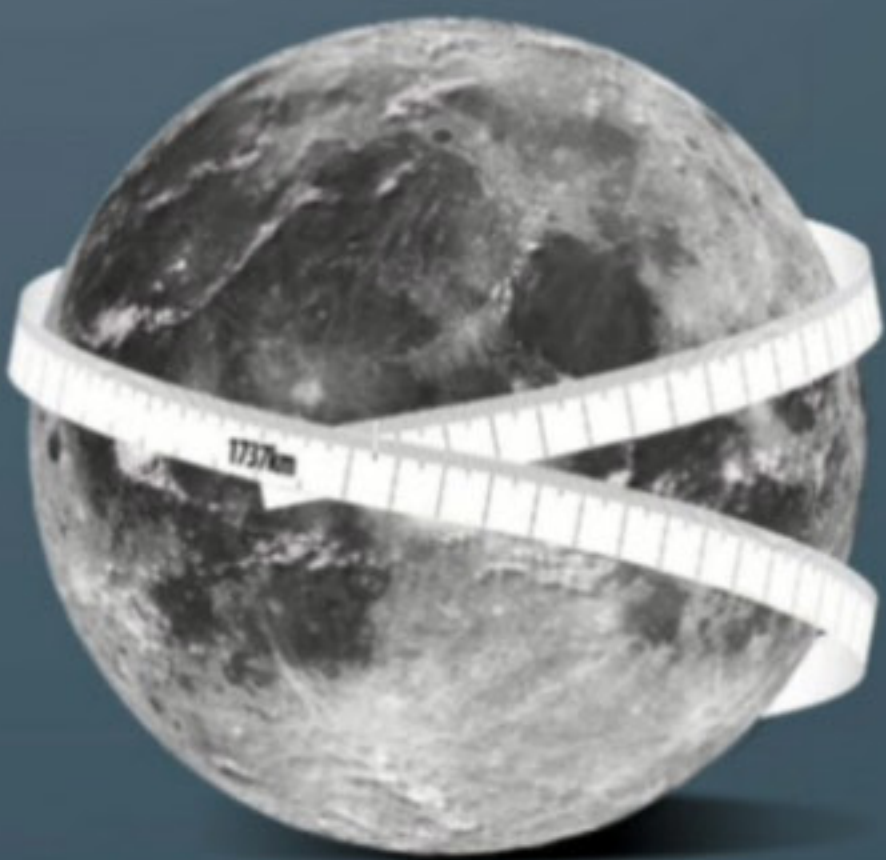


3,700km/h (2,300mph)
Speed of the Moon orbiting Earth

27.3 days
The Moon takes about 27 days to complete one orbit



The Moon in numbers



1,738km
Radius of the Moon - just over a quarter of Earth's

0.1654g

Surface gravity. On the Moon you would be one-sixth your Earth weight

5,000 metres

Height of the highest mountains on the Moon - taller than Mont Blanc

1972

The last time anyone stepped foot on the Moon



30%

Increase in brightness of the Moon when closest to Earth

135 days

to get to the Moon by car travelling at 70mph

Weather forecast

100°C
-153°C



The Moon has virtually no atmosphere, just a sprinkling of evaporating atoms. So there is no wind to create weather systems. In direct sunlight the ground heats to over 100°C (212°F) but in the shade of a crater it can be as low as -247°C (-413°F).



Hours in a lunar day - sunrise to sunrise

1000 wonders of space

From giant craters to supermassive black holes and alien planets: explore **All About Space's** favourite parts of the cosmos

Written by Laura Mears

1 Saturn's Rings

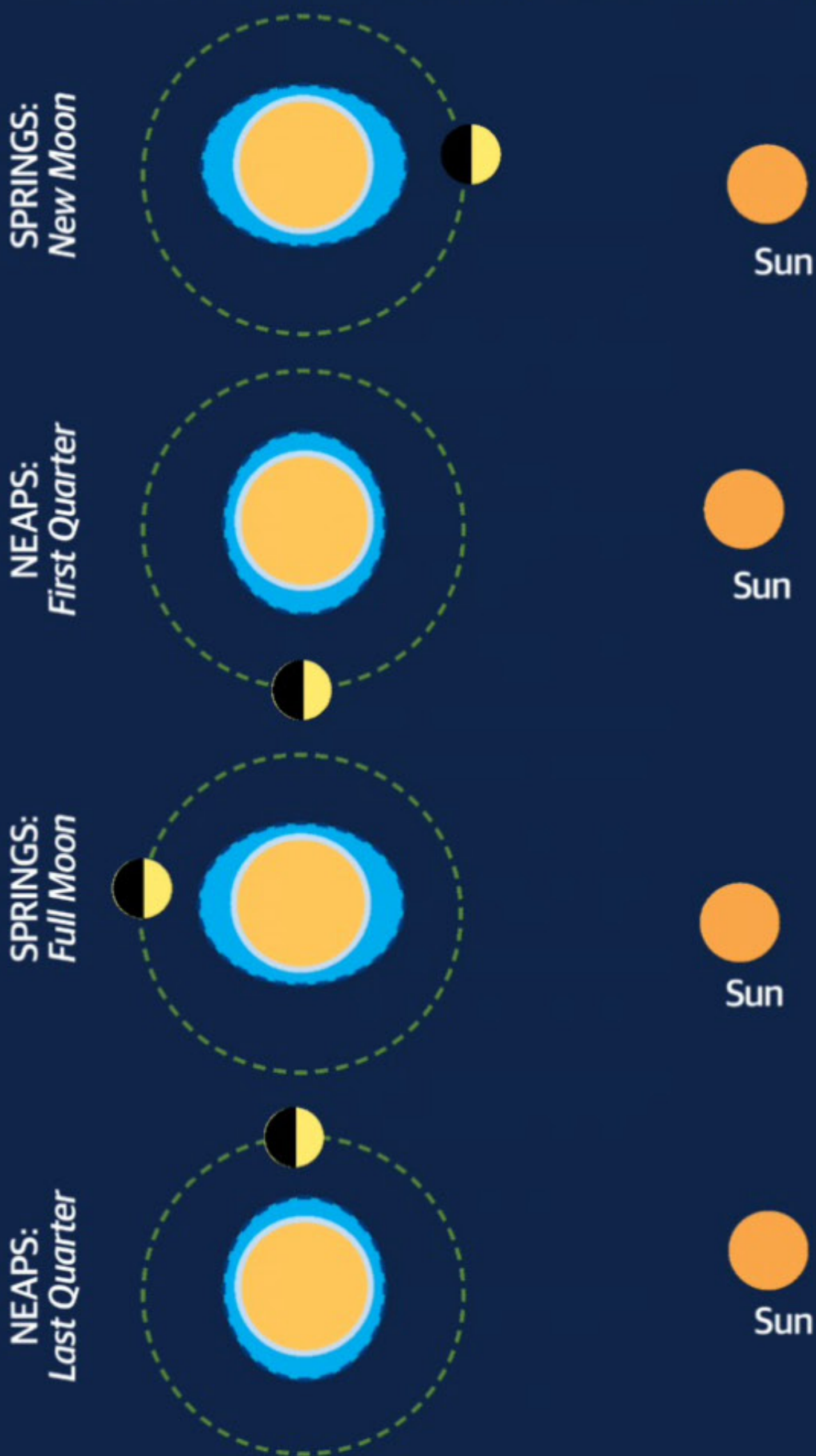
The rings of Saturn are extraordinary. First observed by Galileo Galilei in 1610, these structures are incredibly thin, measuring just one kilometre (0.62 miles) from top to bottom. They're made up of billions of particles of ice and rock, some as large as mountains and others too small to be seen with the naked eye. It's not known for sure how old the rings are, or exactly how they formed, but it is thought possible that the fragments are pieces of shattered moons, smashed to bits by collisions in the not too distant past.

2 Andromeda

Currently sitting at just over 2 million light years from Earth, our closest spiral galaxy Andromeda, and its 100 million stars, are rapidly getting closer. They are rushing towards us at a speed of 402,000 kilometres (250,000 miles) per hour, on a course for collision 4 billion years from now.

3 The Moon

The Moon is a space wonder right on our own doorstep. As it orbits the Earth, its gravity tugs on the oceans, creating a measurable bulge; as the oceans swell, we see the effects on the ground as tides. The Sun has a similar, but smaller, effect, and when the Moon and the Sun are in line, the pull on the oceans adds together, creating extra high 'spring tides' once a fortnight.



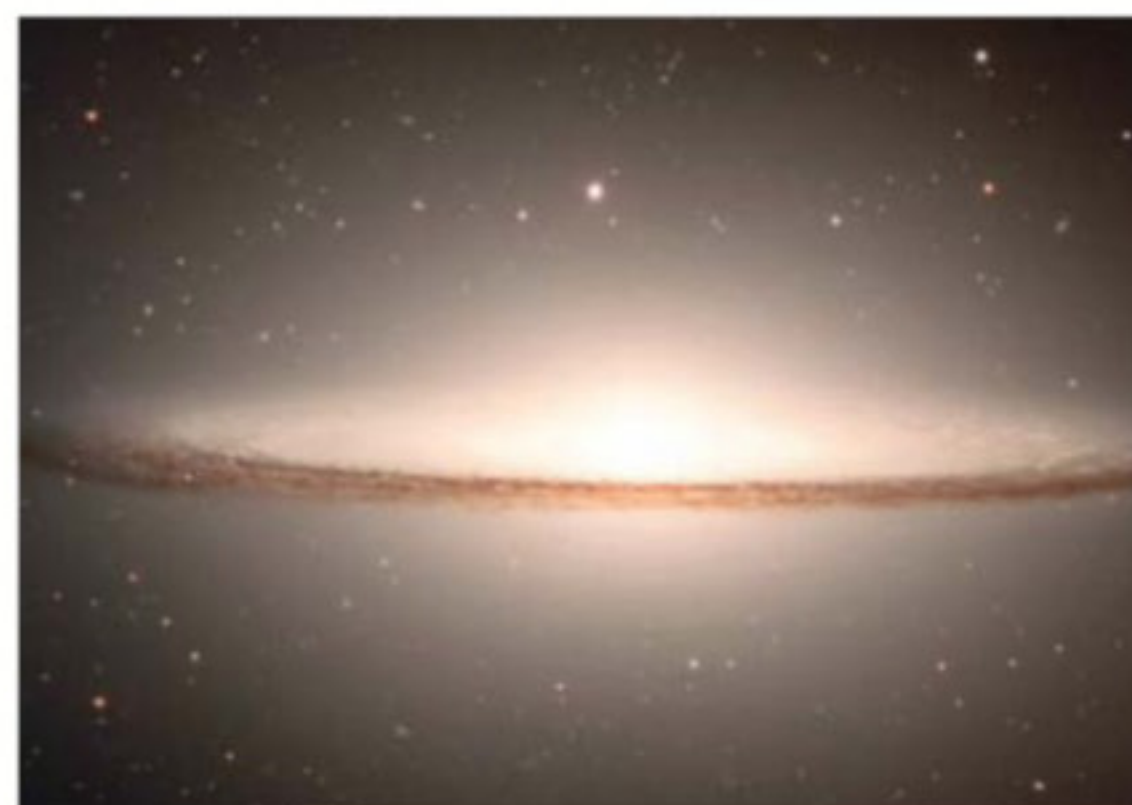
4 The Pillars of Creation

These iconic columns of gas and dust were first imaged by the Hubble Space Telescope in 1995, and in 2015 the pictures were retaken in high definition. Lit by ultraviolet radiation released by massive, young stars in the Eagle Nebula, the pillars are constantly being shaped, heated and eroded, and hidden inside are the infrared traces of brand-new stars.



5 Sombrero Galaxy

Named for its hat-like appearance, the Sombrero is a galaxy within a galaxy. The flat disc, viewed almost side-on from the Earth is the most obvious feature, resembling the wide brim of a hat, but if you look again in the infrared spectrum a much larger elliptical galaxy becomes visible, completely encasing the central disc.



6 Life

As far as we know, Earth is the only planet to harbour living organisms, but chances are there are many more planets out there like our own.

7 Great Red Spot

The width of two Earths, Jupiter's Red Spot is by far the biggest storm in the Solar System, and is given its red colour by the effects of UV light on the clouds.

8 Leonids meteor shower

These meteors shower the atmosphere every November as we pass through a trail of dust and gas left by comet Tempel-Tuttle as it nears the Sun.

9 Methane seas

Weather is not exclusive to water worlds like our own; Saturn's moon Titan has seas, clouds and rain of liquid methane.

10 Giant moon cliff

The tallest cliff in the Solar System is on Uranus's moon, Miranda. Verona Rupes is 20 kilometres (12 miles) deep, and it would take 12 minutes to fall from top to bottom.

11 Acid atmosphere

The atmosphere of Venus is 96 per cent carbon dioxide, and the pressure at the surface is 90 times that on Earth. It has little water, and the clouds are made from corrosive sulphuric acid.

12 Accretion disc

Black holes are surrounded by a spiralling disc of gravitationally trapped matter. It keeps swirling until something disturbs the disc and it tumbles into the void.

13 Vesta's giant mountain

Rheasilvia peak at the centre of the Rheasilvia crater on the asteroid Vesta is 22 kilometres (13 miles) high, rivalling Mars's Olympus Mons volcano as the tallest peak in the Solar System.

14 Valles Marineris

Valles Marineris is Mars's answer to the Grand Canyon, but on a grander scale. It extends for 3,000 kilometres (1,800 miles), and cuts an eight-kilometre (five-mile) deep scar into the planet's surface. Measuring 600 kilometres (370 miles) across, this canyon is thought to have formed 3.5 billion years ago.

15 Hellas Planitia

Hellas Planitia is an ancient impact crater measuring over 2,000 kilometres (1,200 miles) in diameter, and extending down for four kilometres (2.5 miles). This enormous scar on the southern hemisphere is the largest complete crater on the surface of Mars, created by an asteroid impact around 4 billion years ago.

16 Olympus Mons

This imposing mountain is the tallest volcano in the Solar System; standing at an incredible 25 kilometres (16 miles) tall. It easily eclipses the tallest volcano on Earth, Mauna Loa. On Mars, the surface is static, so lava continues to erupt in one position, generating a volcano of truly gargantuan proportions.

17 Faces on Mars

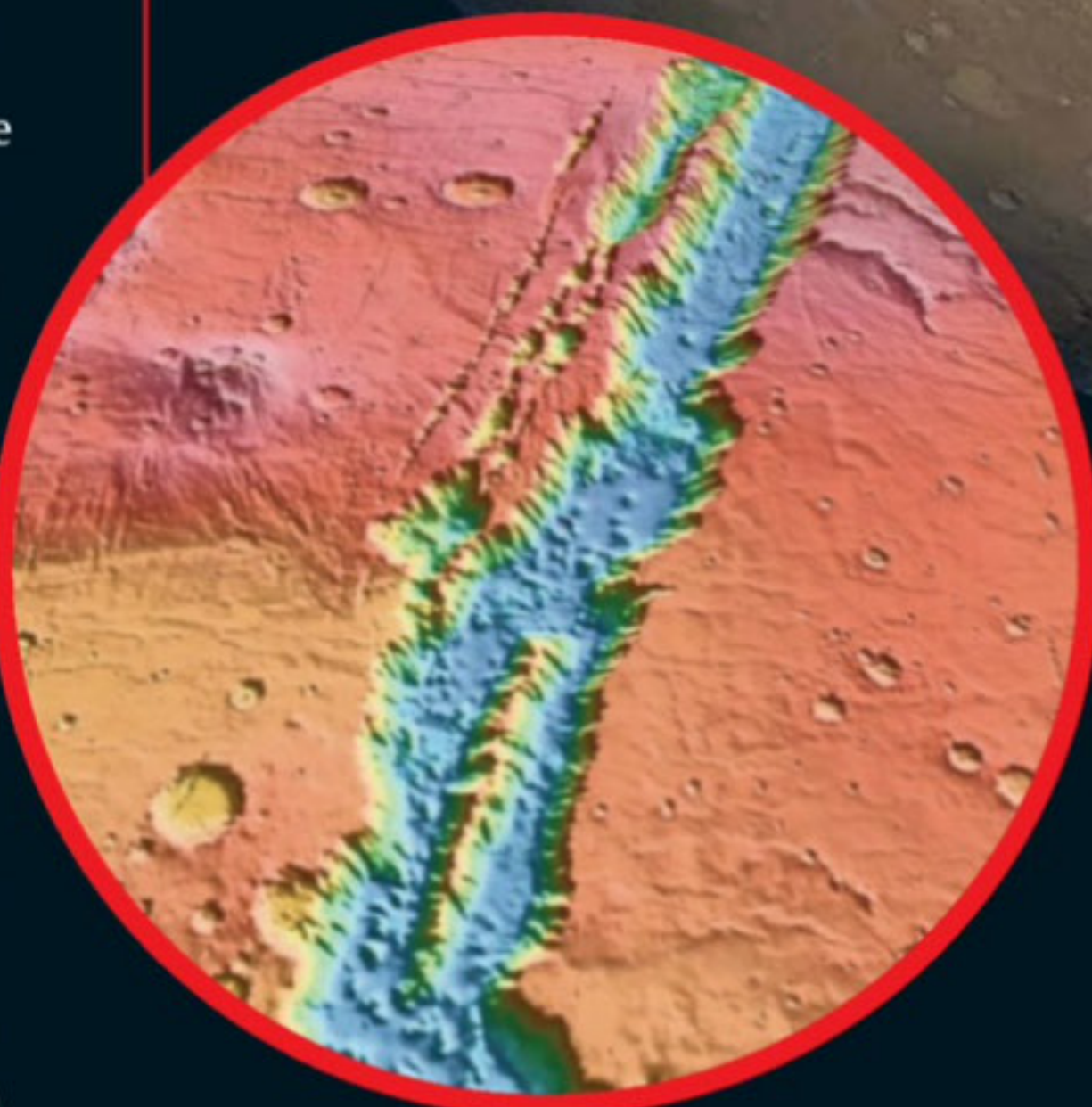
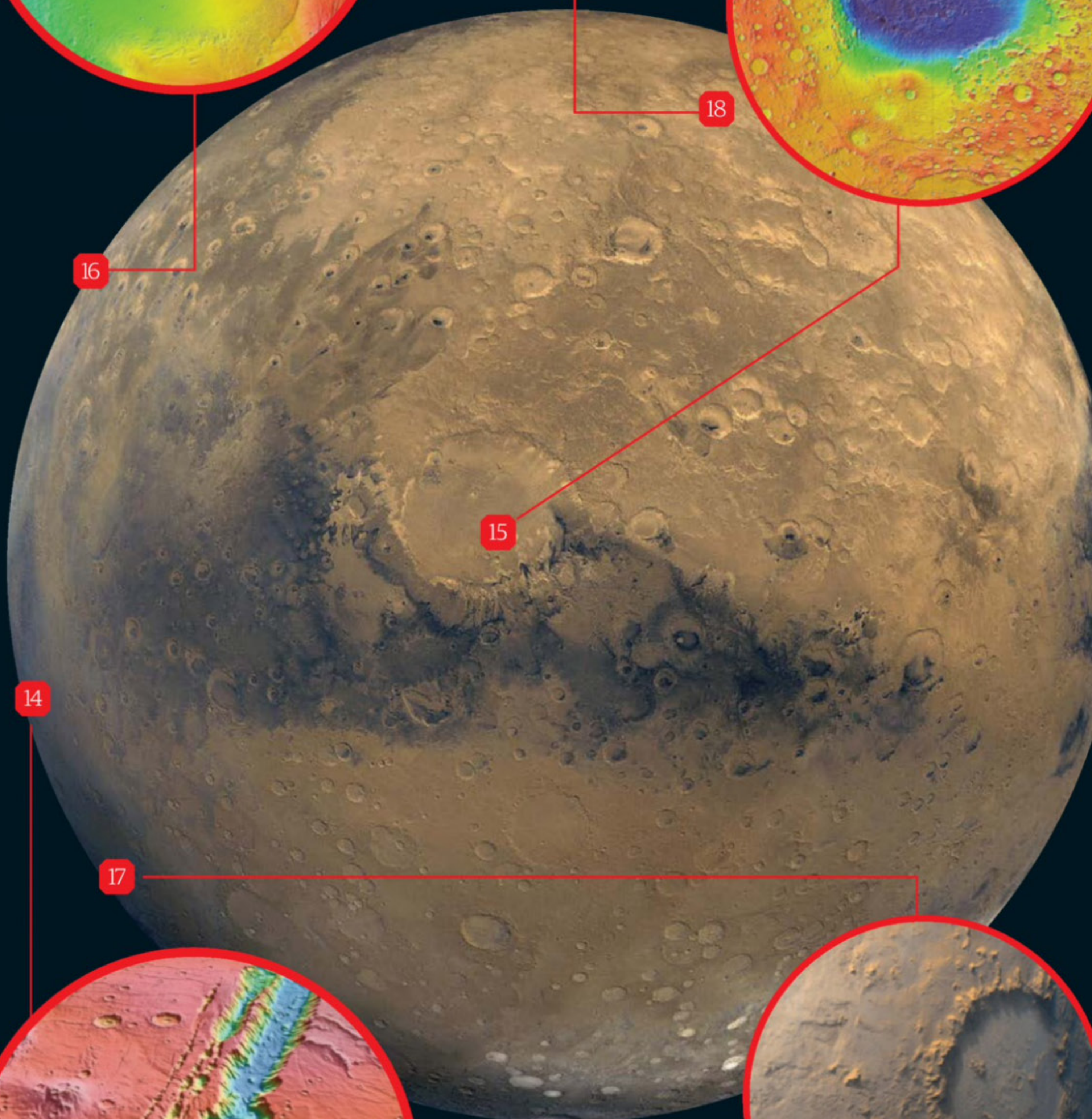
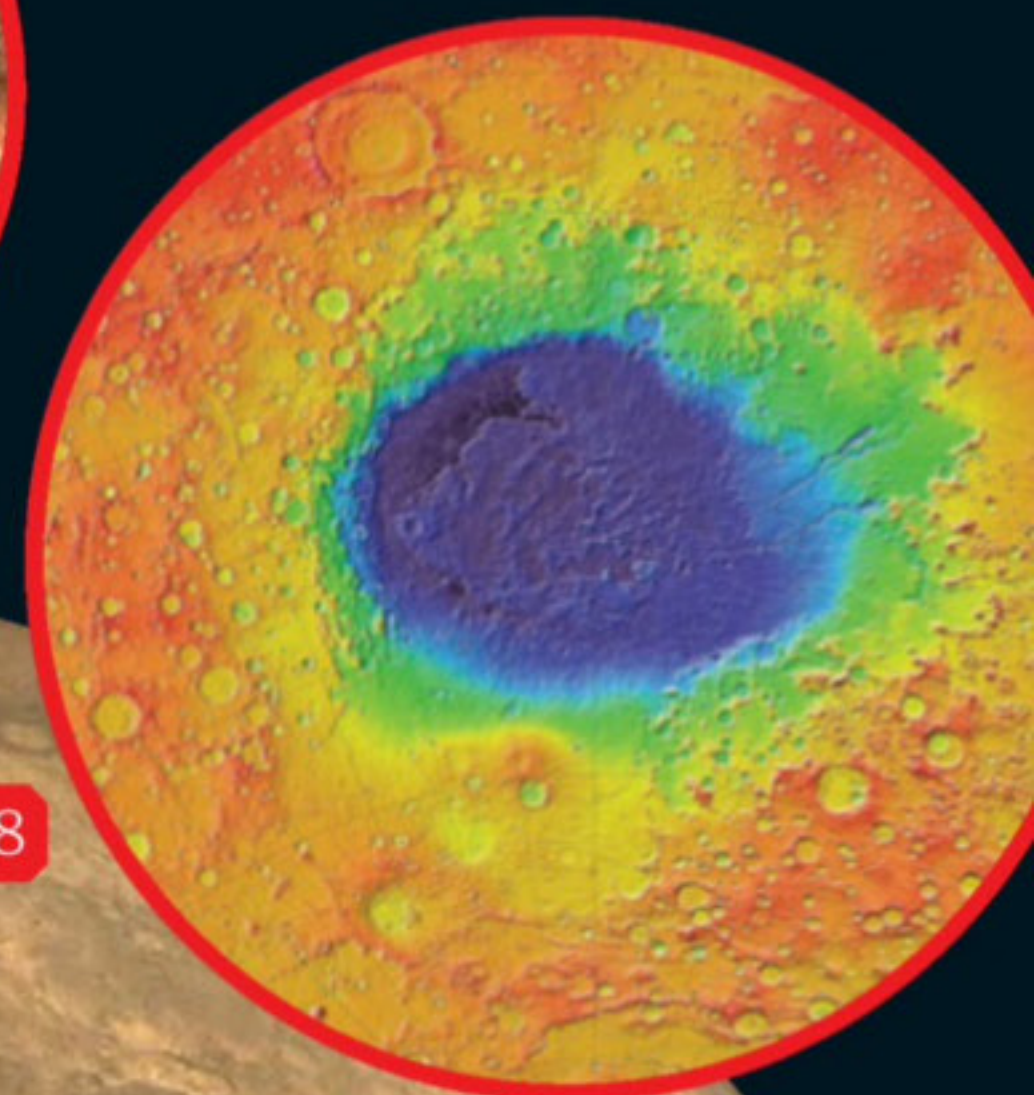
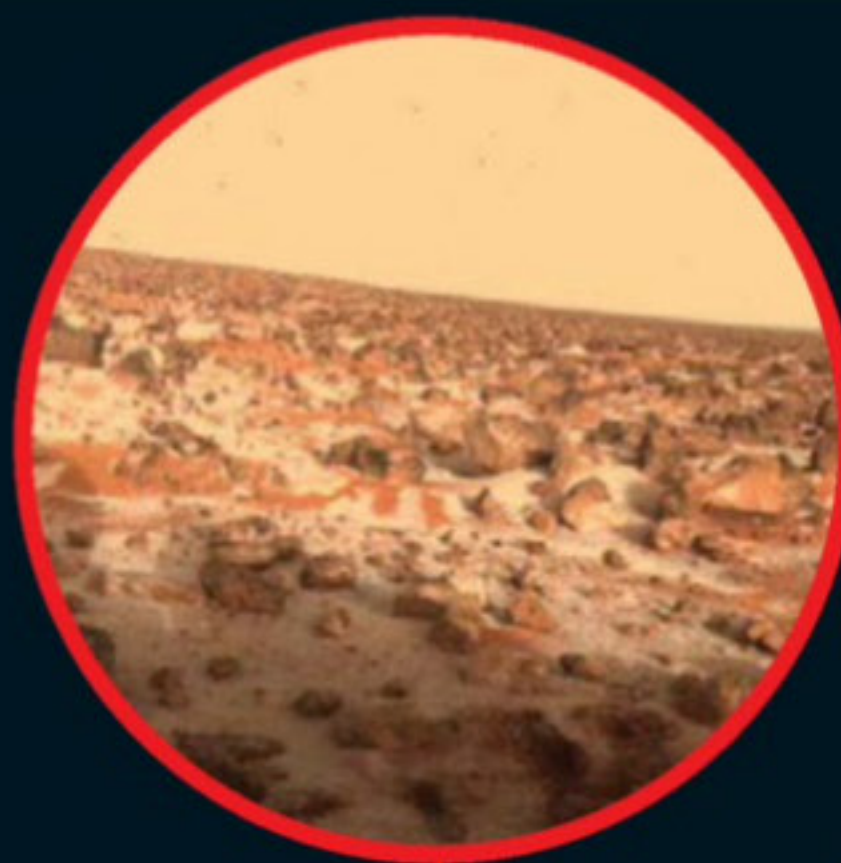
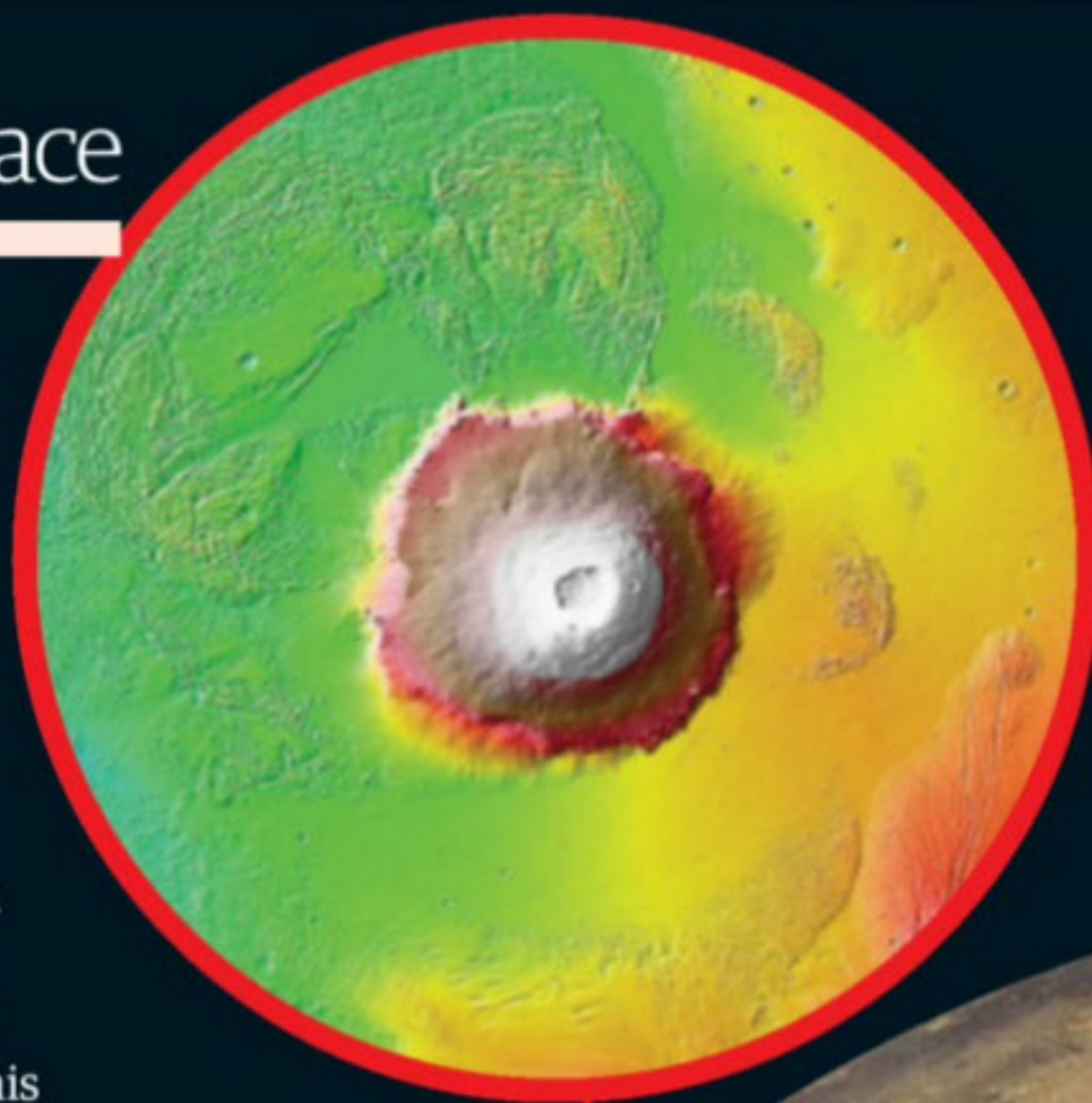
When Viking 1 made its mission to Mars in the Seventies it was greeted by a strangely familiar sight; two faces were staring back from the bare rocks on the surface. Unfortunately, high-resolution images of these features revealed both to be natural landforms, and not sculptures created by intelligent life.

18 Utopia Planitia

The crater of this Martian impact basin contains landforms known as 'thermokarst', with geometrically shaped lines and depressions with scalloped edges. When Viking 2 arrived in 1979, it found a thin layer of ice on the surface, and the lines in the ground are thought to have been formed by wedges of subsurface ice.

19 Mars haboobs

Mars is coated in a layer of fine magnetic dust, and experiences some incredibly violent weather; warm air in the deep Hellas Basin can generate storms that engulf the entire planet.





20 Red Square Nebula

The unusual geometric shape of this nebula found in the constellation of Serpens remains an astronomical mystery, but the leading hypothesis is that we are looking at the side of several cones of gas released by the star or stars sitting at the centre. The cones are at right angles to one another, producing the shape of a square, but if we looked from a different angle we would be able to see directly into one of the cones, and it would appear as a red ring.



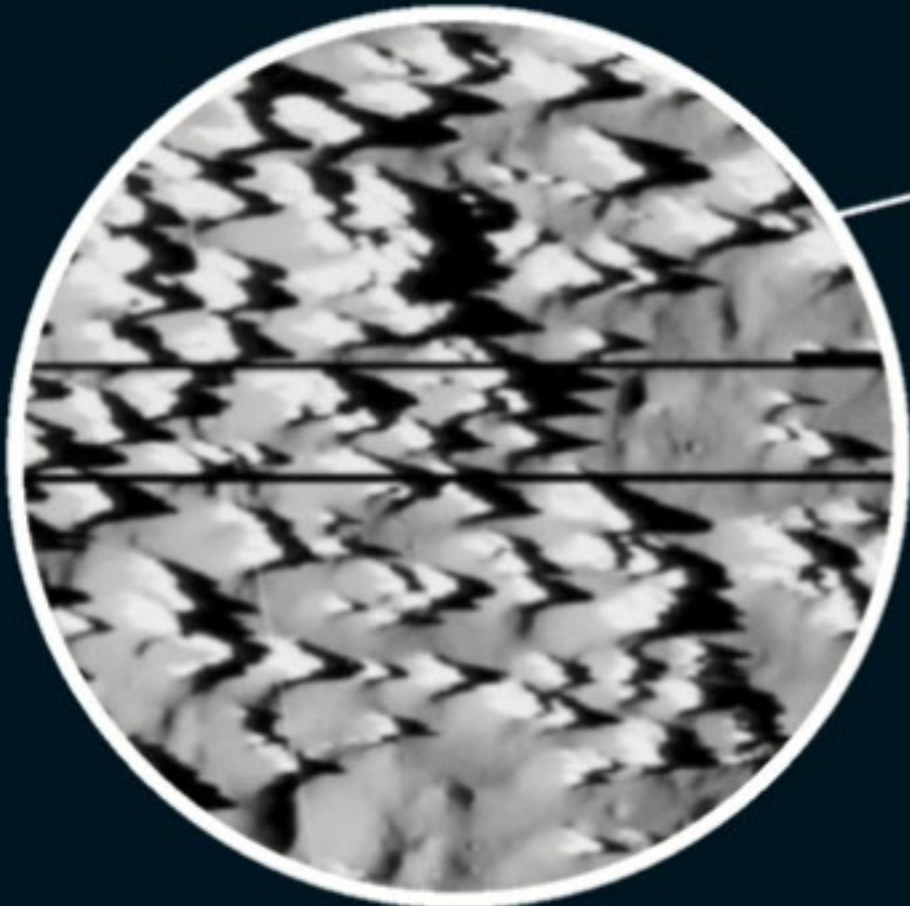
21 The diamond ring

At first glance, this photograph captured by the European Southern Observatory's Very Large Telescope might look like a single object in the form of a cosmic diamond ring, but in reality, it is the result of an interaction between two objects. The ring itself is formed by the blue bubble of a planetary nebula known as Abell 33, created when the atmosphere of a dying Sun-sized star ballooned into space, and the 'diamond' is a well-positioned bright foreground star.

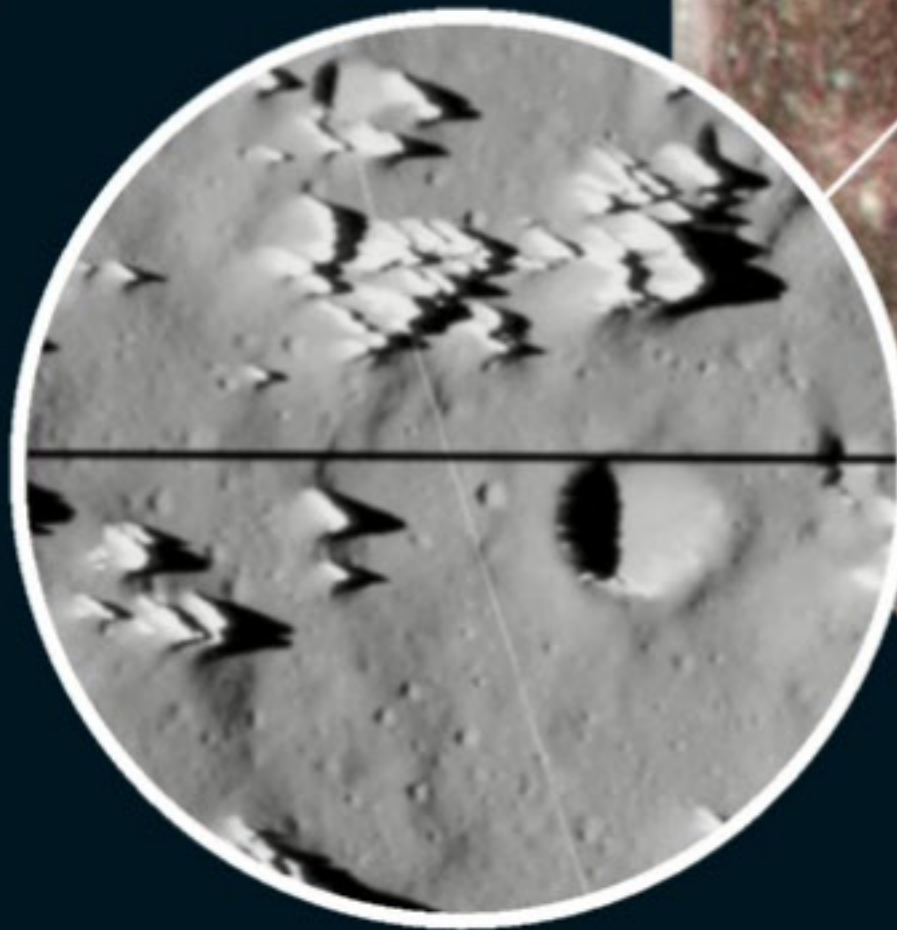
22 Callisto ice spires

Jupiter's moon Callisto was thought to be a dead object, an ancient cratered world coated in a layer of ice, but images captured by NASA's Galileo spacecraft in 2001 revealed spires jutting out from the

surface. The icy spikes are coated in dark dust which absorbs heat from the Sun, causing the ice to melt, and gradually eroding the surface.



The surface of Callisto is coated in spiky mounds of ice, surrounded by dark puddles of dust

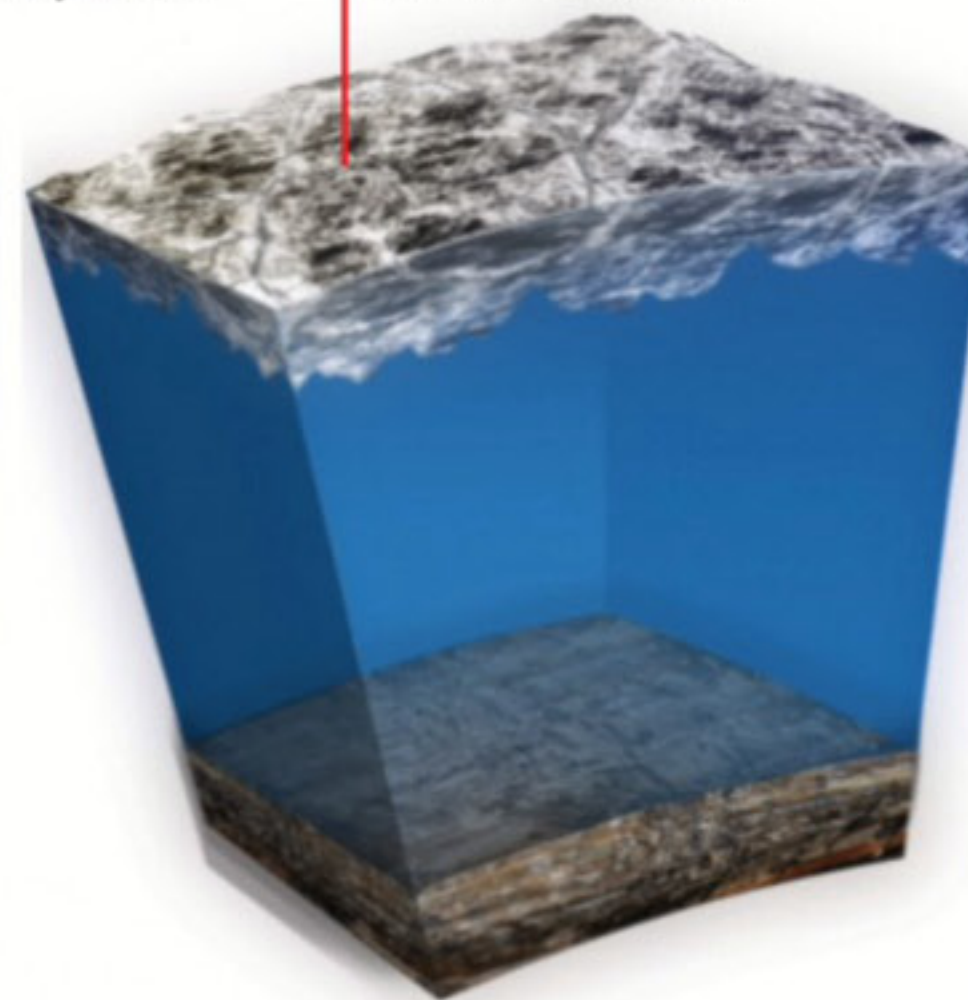
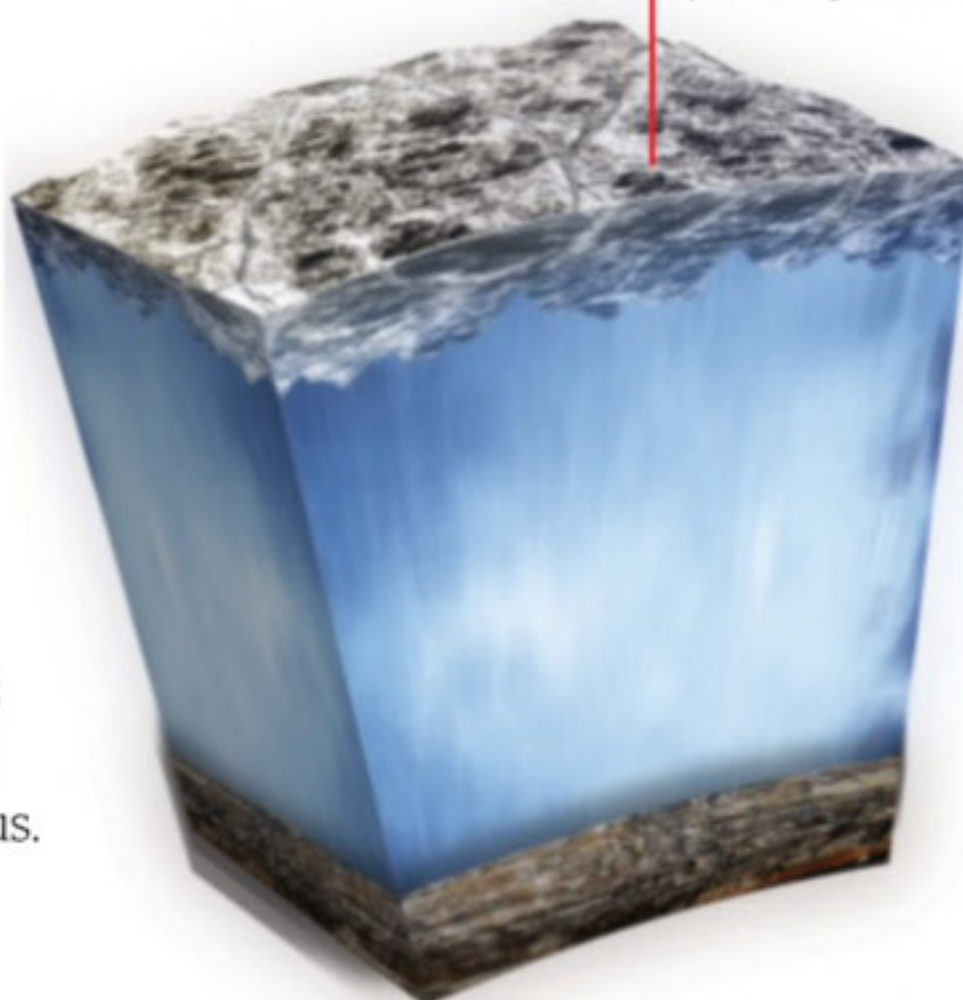


23 Subsurface oceans

Beneath the surface of seemingly frozen moons there are potentially vast quantities of liquid water. In the far reaches of the Solar System the temperature plummets, but friction caused by the gravitational interactions between a moon and its parent planet could melt subsurface ice, resulting in hidden oceans. The tidal motion of these oceans as the moon orbits would help to keep the water in liquid form. The best candidates for subsurface water in the Solar System are Jupiter's moons Europa, Callisto and Ganymede, and Saturn's moons Mimas and Enceladus.

■ **Warm convecting ice**
Europa has a magnetic field, indicating that something is conducting electricity below its surface; one explanation is partially melted icy slush.

■ **Liquid ocean under ice**
Europa is still warm at its core, so it is thought more likely that the water inside is truly in liquid form, making up a salty subsurface ocean.



24 Dark nebulae

These clouds are so dense that no light can pass through; it is all absorbed, making it appear as though there are gaps in space.

25 Shooting stars

These wonders of the night sky have long fascinated humanity. They happen when chunks of dust and rock burn up as they pass through the atmosphere.

26 Stellar magnets

Magnetars are neutron stars with extreme magnetic fields. They are rare and unpredictable, suddenly erupting with gamma-ray bursts before going quiet.

27 Titan

Saturn's moon Titan is unique in the Solar System; it is the only satellite with its own atmosphere, and is covered in seas of liquid ethane and methane.

28 Tea-temperature star

The nearby brown dwarf star, CFBDSIR 1458+10B, is part of a binary system and has a surface temperature comparable to a freshly made cup of tea.

29 Hypervelocity stars

Some stars travel at speeds over 3.2 million kilometres (2 million miles) per hour, fast enough to escape the gravitational pull of their parent galaxy.

30 Himiko

Also known as the Lyman-alpha blob, Himiko is an enormous ancient galaxy; it is so far away that we are looking 800 million years into the past.

31 Hamburger Galaxy

Positioned edge-on to Earth, this spiral galaxy appears to us like a flat red-orange disc of stars and dark dust, reminiscent in shape of a popular American food.

■ Silicon-based materials

Around the core is a second molten layer containing silicon-based materials, such as silicon carbide (SiC) or enstatite (MgSiO₃).

■ Surface graphite

The lower pressures at the surface would result in a layer of graphite, and depending on the atmosphere and temperature, there could also be hydrocarbon weather.

■ Molten iron core

Like Earth, the core of a diamond planet is thought to be composed of molten iron, or a combination of iron and carbon (molten steel).

■ Diamond layer

If there is enough pressure beneath the surface, a rigid band of crystals could form, creating a thick layer of diamond.

32 Diamond planets

Our own Solar System is dominated by oxygen and the terrestrial planets inside it are made from silicon-based rocks. But elsewhere in the universe it is a different story; in carbon-dominated systems, some planets are thought to be made from diamond. One of the first candidates for

a diamond planet is a super-Earth known as 55 Cancri E. It is 40,000 light years away, twice the size of Earth and almost eight times the mass, and beneath a surface of graphite, planetary scientists think it could contain a thick shell of precious stones and other crystal structures.

35 Cosmic Microwave Background

The cosmic microwave background (CMB) is evidence of the Big Bang written all over the fabric of the universe. It was discovered by Bell Telephone Laboratories in the Sixties, and was originally little more than a nuisance, interfering with radio communications, but it soon became clear that this background radiation was special. The CMB represents

the oldest light in the universe; the thermal radiation left over from the Big Bang. The early universe was hot and dense but over the last 13.7 billion years, it has stretched and cooled. As the universe has expanded, the heat signature expanded with it, leaving behind a visible fingerprint in the form of a uniform layer of microwave radiation spread across the sky.

■ Very early universe

In the earliest stages of the universe, it was so hot and dense that free electrons scattered photons, and no light could escape.

■ Creation of the CMB

The first light of the universe was released 380,000 years after the Big Bang, when the universe had cooled to around 2,700°C (5,000°F).

■ Expansion

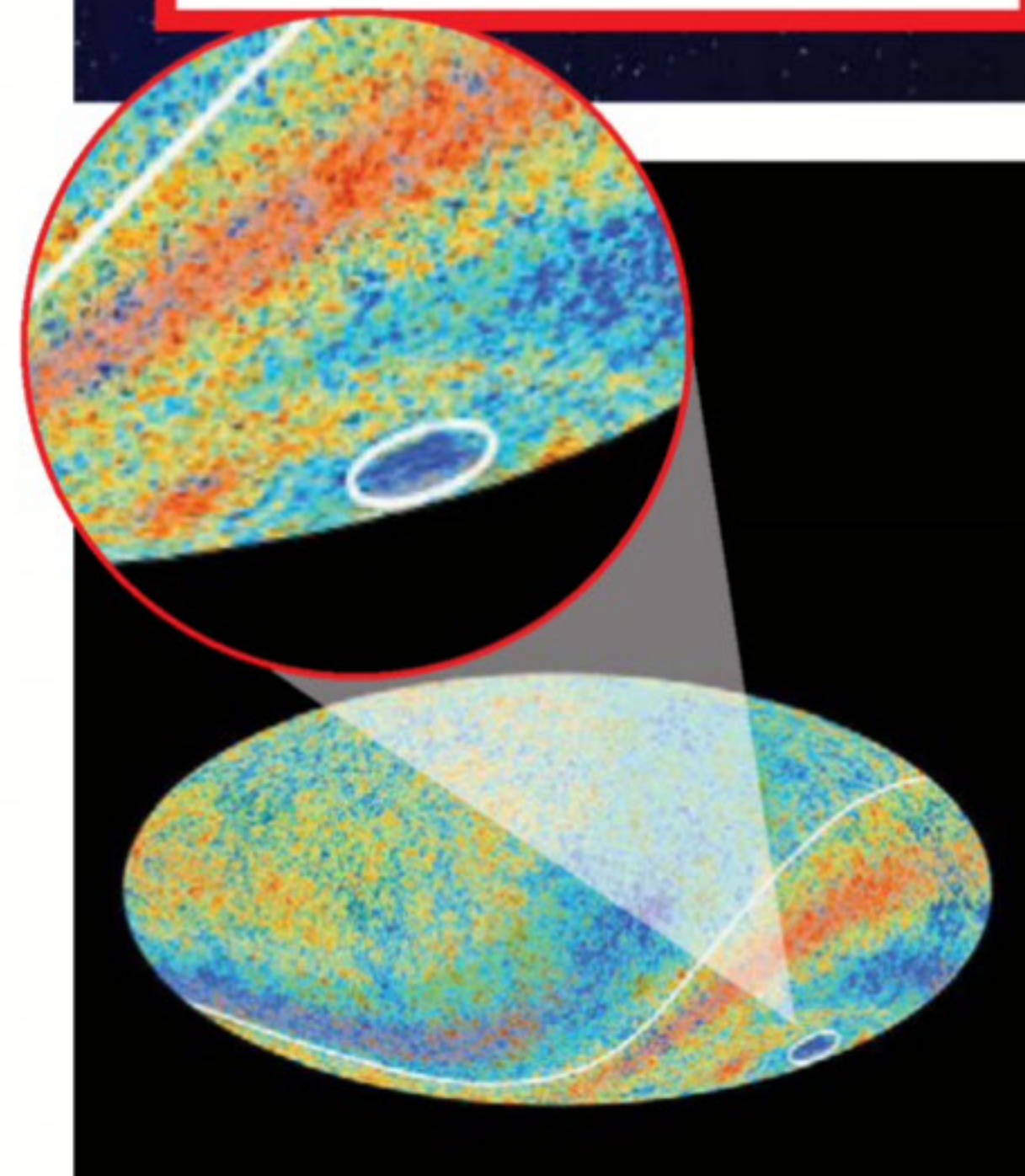
As the universe has continued to expand, the first light has expanded with it, and the thermal signature is now just 2.725 degrees above absolute zero; visible as microwaves.

33 Massive water reservoir

The quasar APM 08279+5255 hides a black hole 20 billion times the Sun's mass, and contains an ancient water cloud. The gas surrounding the black hole contains 140 trillion times more water than Earth's oceans.

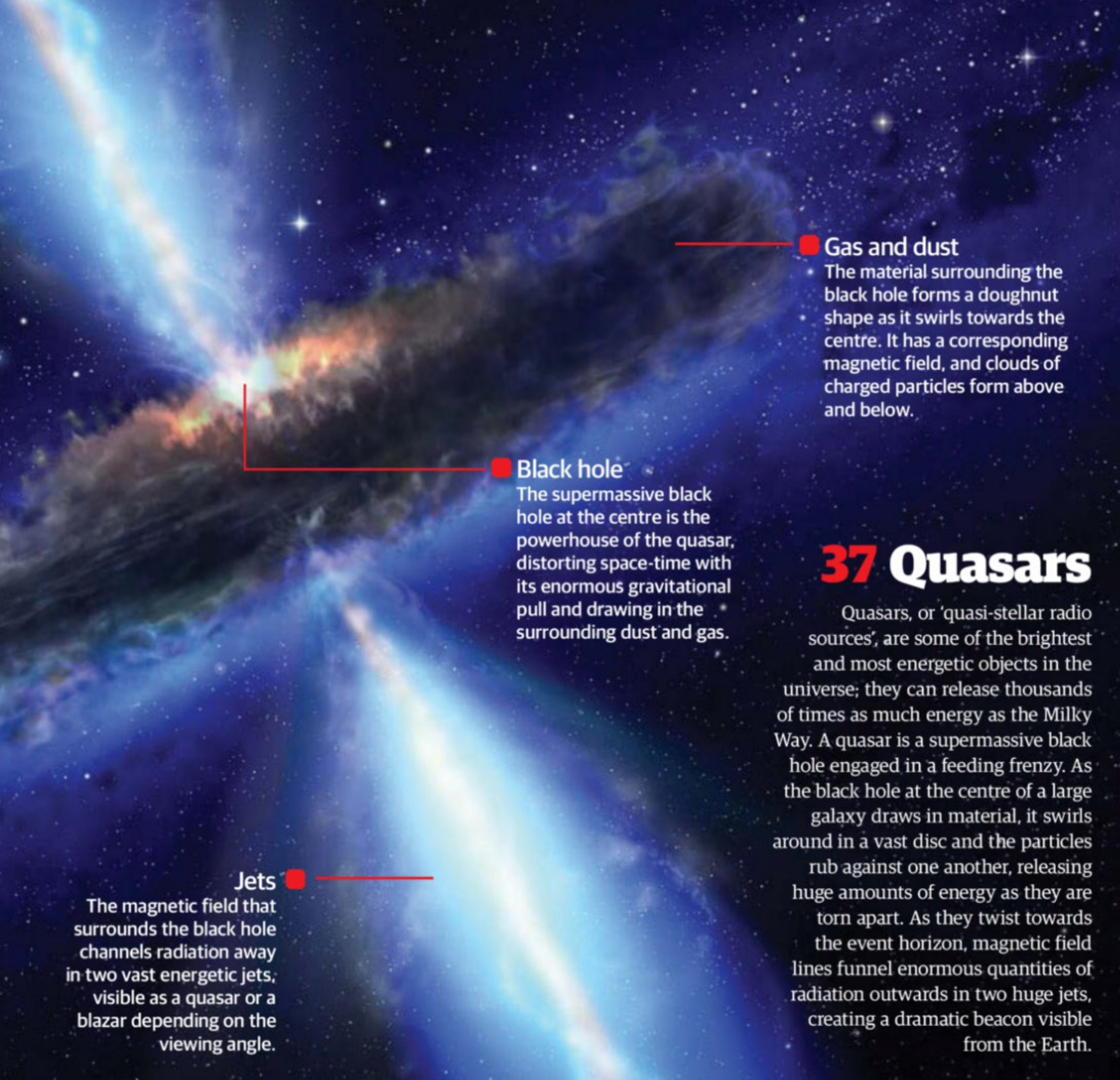
34 Gamma-ray bursts

Once a day, a random point in the sky blazes with an intense pop of energy known as a gamma-ray burst. Each burst is thought to be the final firework display of a massive star as it collapses down to form a black hole.



36 The Cold Spot

The Cosmic Microwave Background (CMB) (see wonder number 35), is the afterglow of the Big Bang, and is relatively uniform across the entire sky, however there is a strange cold spot in the lower right-hand corner. The chance of this happening at random is around 1 in 100, and its presence is puzzling cosmologists. Possible explanations put forward include an enormous supervoid, a defect known as 'texture', and even the presence of a parallel universe.



● Gas and dust

The material surrounding the black hole forms a doughnut shape as it swirls towards the centre. It has a corresponding magnetic field, and clouds of charged particles form above and below.

● Black hole

The supermassive black hole at the centre is the powerhouse of the quasar, distorting space-time with its enormous gravitational pull and drawing in the surrounding dust and gas.

37 Quasars

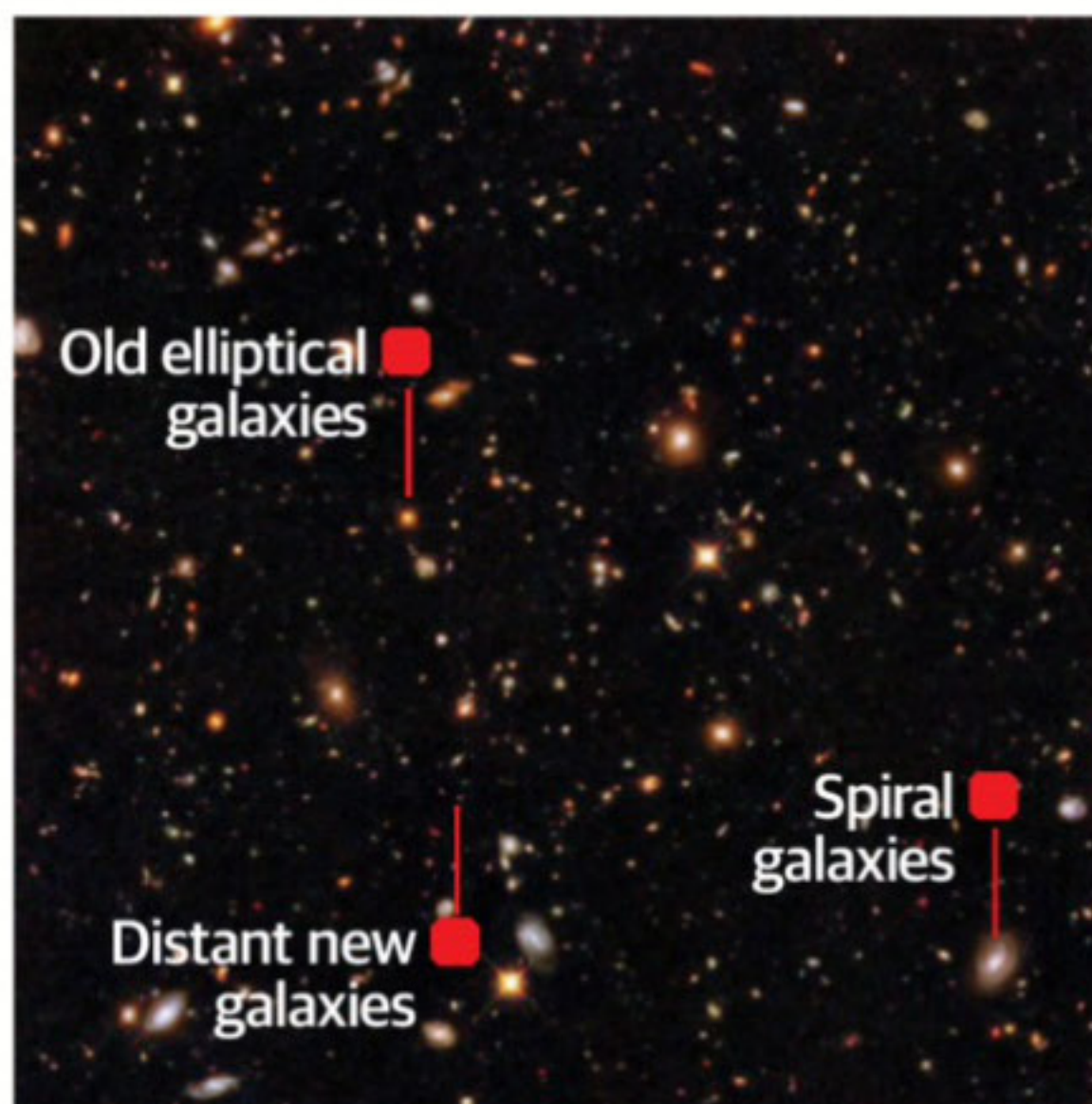
Quasars, or 'quasi-stellar radio sources', are some of the brightest and most energetic objects in the universe; they can release thousands of times as much energy as the Milky Way. A quasar is a supermassive black hole engaged in a feeding frenzy. As the black hole at the centre of a large galaxy draws in material, it swirls around in a vast disc and the particles rub against one another, releasing huge amounts of energy as they are torn apart. As they twist towards the event horizon, magnetic field lines funnel enormous quantities of radiation outwards in two huge jets, creating a dramatic beacon visible from the Earth.

● Jets

The magnetic field that surrounds the black hole channels radiation away in two vast energetic jets, visible as a quasar or a blazar depending on the viewing angle.

38 Hubble Deep Field

One of the most astonishing things about space is what appears when you point a telescope at nothing. Between 2003 and 2004, the Hubble Space Telescope was aimed at an empty portion of the sky in the constellation of Fornax and in the eight years that followed, it kept returning, creating an even more detailed image of what appeared to be a blank patch of sky. The resulting images revealed a sea of galaxies, stretching back in space and time 13.2 billion light years, almost to the birth of the universe.



39 Stephan's Quintet

This cluster of five galaxies was discovered in the 19th century and demonstrates the effects gravity on a monumental scale. Three of the galaxies are so close that immense gravitational tides have made visible changes to their structure, pulling on their spiral arms and distorting their shapes as they twist towards an inevitable collision. The bluer galaxy at the bottom left of the image is an interloper, 240,000 light years away from the others, it is not actually part of the group.



40 Dark energy

We know little about dark energy other than that it is accelerating the expansion of that which followed the Big Bang. It is thought to make up between 68 and 71 per cent of the universe.

41 Dark matter

Between 24 and 27 per cent of the universe is thought to be composed of dark matter, made up of subatomic particles that interact only weakly with 'ordinary' matter.

42 Rare types of matter

'Normal' atomic matter, made up of protons and neutrons makes up just five per cent of the universe. The remainder is dark matter and dark energy, neither of which have ever been directly detected.

43 Red dwarfs

These small, dim stars burn so slowly that they are thought have lifespans longer than the total age of the universe, meaning that none are yet old enough to have died.

44 Asteroid belt

Between Mars and Jupiter lies a band of leftovers from the beginnings of the Solar System; either the remnants of a planet that failed to form, or the fragments of a broken one.

45 Oort cloud

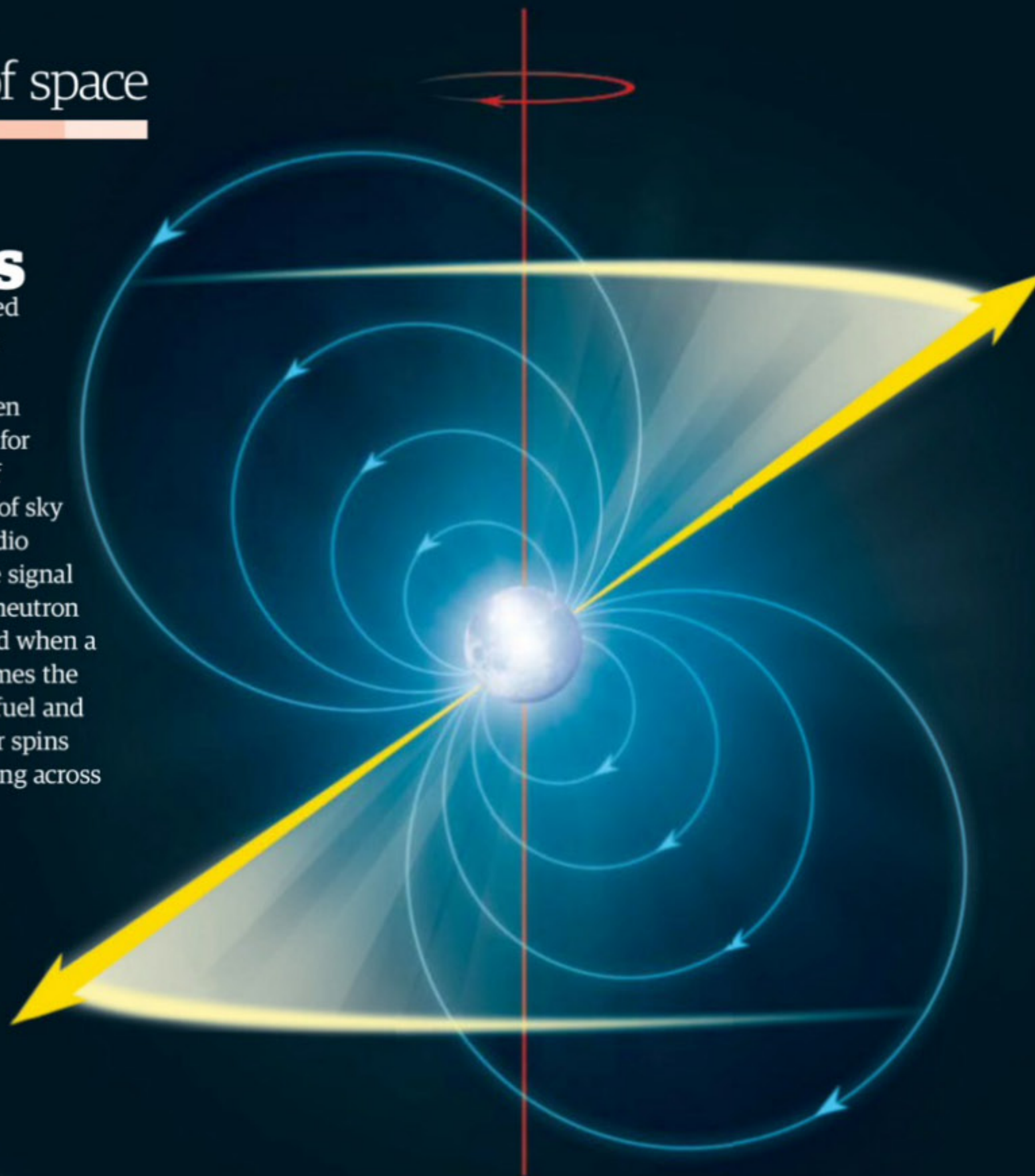
The Solar System is encased in a sphere of icy objects, collectively known as the Oort cloud. The Sun's gravity at that distance is so weak that passing objects can send comets hurtling inwards.

46 Backwards spiral galaxy

The arms of spiral galaxies trail backwards as they turn, but NGC 4622 is turning in the same direction that its arms point, possibly as the result of a collision that upset its spin.

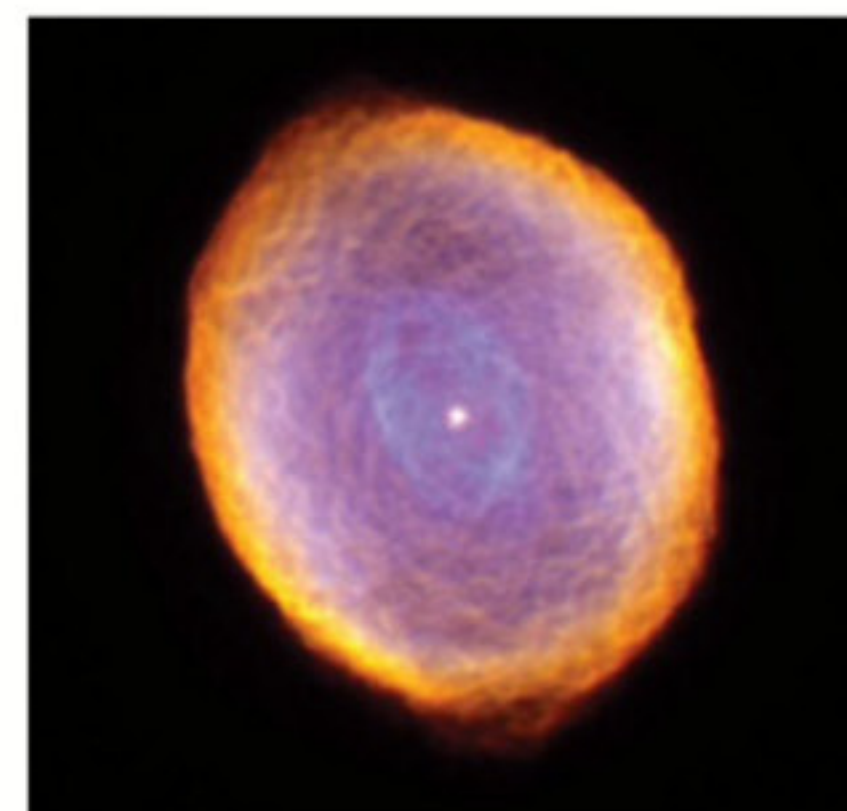
47 Pulsars

When pulsars were discovered in 1967, Jocelyn Bell thought she might have intercepted communications from an alien civilisation. While searching for the high-energy twinkling of quasars, she noticed a patch of sky emitting regular pulses of radio waves every 1.3 seconds. The signal was actually generated by a neutron star. Neutron stars are created when a star between eight and 25 times the mass of the Sun runs out of fuel and collapses. As the neutron star spins its radio jets spin too, sweeping across the sky in regular pulses.



48 Hoag's Object

This unusual object is a ring galaxy, one of the rarest galaxy types in the universe. At the centre is a spherical bulge of old orange-red stars, and around the edges is a ring of bright blue hot young stars. Other ring galaxies are thought to have formed following a collision, or due to a rapidly spinning central bar, but the origin of Hoag's Object is unknown. If you look inside, another ring galaxy is visible far in the distance.

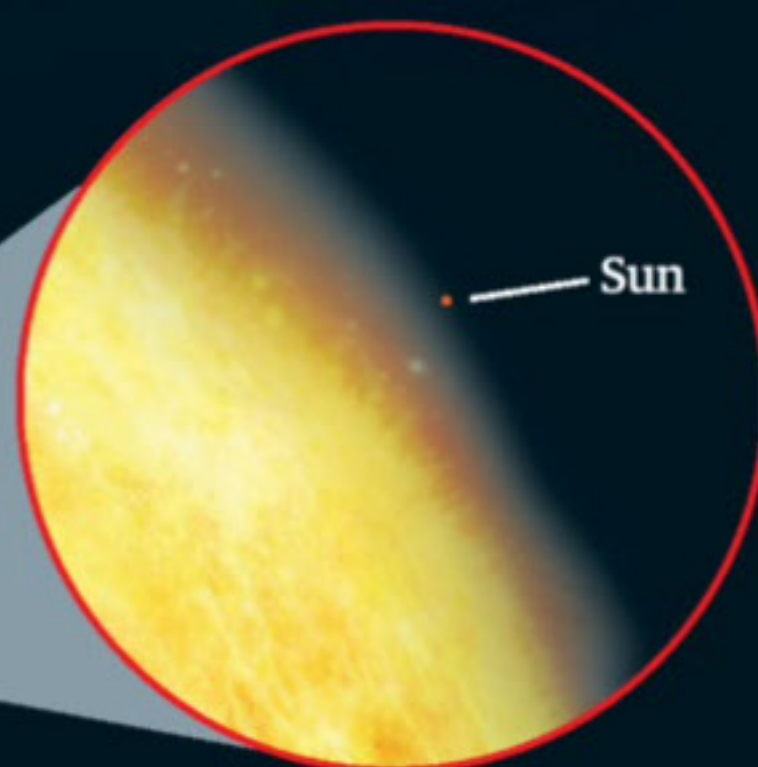
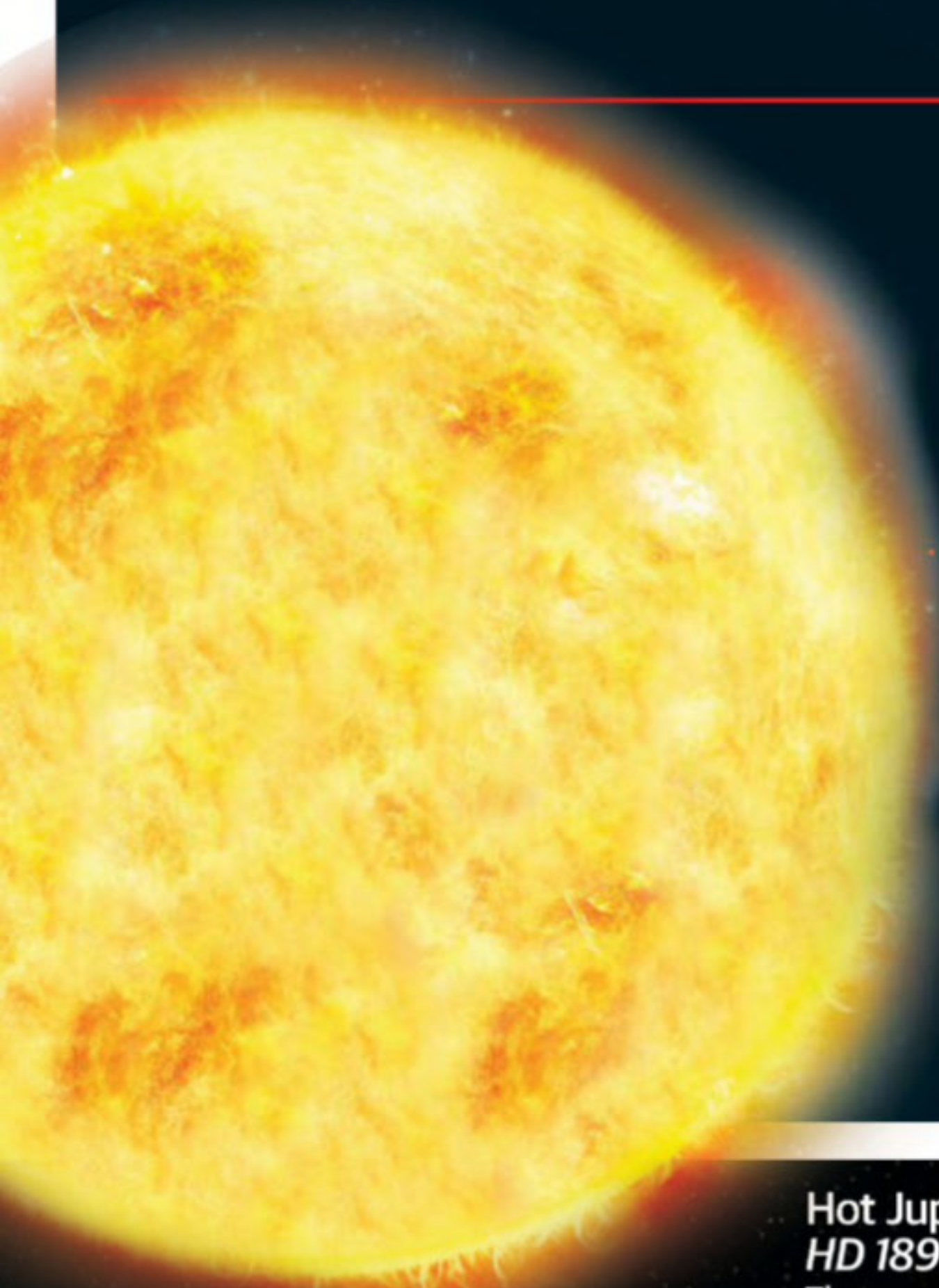


49 Spirograph Nebula

The star at the centre of these geometric swirls used to be like our own Sun, but a few thousand years ago it started running out of fuel and ballooned to become a red dwarf. Since then, its fuel has disappeared, and its envelope has begun expanding. The white dwarf now forming at the centre is unpredictable, and scientists believe that its erratic winds could be making these strange patterns in its nebula.

50 Massive star

VY Canis Majoris is one of the largest stars in our galaxy; 2,000 times the size of the Sun, and between 30 and 40 times the mass. Within just a few tens of millions of years, VY Canis Majoris will collapse, creating a supernova that will spray the surrounding space with water, silicone compounds and carbon, giving rise to a new generation of smaller more Sun-like stars.



51 Exoplanets

Until 1994, the planets of the Solar System were the only planets that we were aware of in the universe. It was always thought likely that other stars had companions. The first exoplanet was found orbiting a pulsar and, just a year later, in 1995, another was discovered orbiting a Sun-like star. NASA's JPL lists a total of 5,003 known exoplanets.

Hot Jupiter HD 189733b

These enormous gas giants orbit close to their parent stars, blocking the light as they pass and making their presence easy to detect. Some, like HD 189733b, orbit closer than Mercury.



Chthonian planet Osiris (HD 209458b)

Gas giants orbiting close to their stars are bombarded by radiation and solar winds, and evaporate rapidly. Chthonian planets are the hypothetical rocky remnants that will be left behind.



Hot Neptune Gliese 436 b

These Neptune-sized planets orbit close to their parent stars, and a year on the surface passes quickly, making them easy to detect from far away.



Water world Kepler 22b

This group of ocean planets are composed mostly of water. Some are thought to have thick atmospheres, supporting liquid water on the surface, but others are hot, steamy and unstable.



52 Horsehead Nebula

This remarkable pillar of dense dust and gas is named after the horse-like head and neck at its tip. It is part of a larger optical nebula known as Barnard 33, and is visible in pink silhouette thanks to an extremely bright five-star system, Sigma Orionis – part of the constellation of Orion. The Horsehead pokes out of a larger cloud system, and inside its dark interior new low-mass stars are being born.

53 Einstein Cross

One of Albert Einstein's greatest ideas was that the universe is made from a fabric called space-time, and that mass causes this fabric to bend, like balls sitting on a trampoline. Incredibly, there is evidence of it happening right before our eyes. The Einstein Cross is a single quasar, but it looks like four because a galaxy sitting in front of it bends space-time, curving the light as it passes, and acting like a lens to duplicate the image.

54 Caloris Basin

This enormous impact basin measures 1,500 kilometres (930 miles) in diameter, and is one of the hottest places on Mercury. Its perimeter is studded by volcanic vents, visible here as bright orange hot spots, and its interior is pockmarked by hundreds of more recent impacts.

55 Mercury double sunsets

When Mercury is at its closest point to the Sun, it travels so quickly that its rotational speed can't keep up, and after the Sun sets it reappears and sets again.

56 Aurorae

The aurora borealis and the aurora australis are some of nature's most spectacular wonders. The Sun releases a stream of charged particles called the solar wind, and this feeds into the magnetosphere around our planet, dislodging other particles and slamming into the gases that make up the atmosphere. These collisions excite the gas molecules, and make them glow. Depending on the height and the type of gas hit different colours are made.

57 Supernovae

When massive stars die they go out with a bang, releasing as much energy as the Sun will during its entire lifetime in just fractions of a second.

58 South Pole-Aitken Basin

The south pole of the Moon has a spectacular impact crater, covering an area measuring around 2,600 kilometres (1,600 miles), and deeper than the height of Mount Everest.

59 Chelyabinsk meteorite

This 19-metre (62-foot) wide asteroid exploded in mid-air over Russia in 2013; an event that happens on this scale approximately once every 30 years.

60 Cataclysmic variable stars

In some binary systems, a white dwarf and a larger star, like a red giant, orbit close to one another. The white dwarf feeds on its companion, creating an accretion disc that glows.

61 Total solar eclipse

These rare events are only possible thanks to the chance position of the Moon; at its current distance, the Moon appears the perfect size in the sky to completely cover the Sun's disc as they line up. Read more about them in our feature on page 64.

Super-Earth HIP 116454b

These planets have a mass greater than Earth, but lower than Neptune. Despite the name, not all super-Earths are Earth-like – some are blisteringly hot, others are frozen, and some are made of gas.

Gas giant GJ 540b

These enormous planets, just like Jupiter and Saturn, are several times the mass of Earth, and are composed mostly of gas, with a molten rocky or metallic core.

Terrestrial 55 Cancri e

These are the planets that, like Earth, are composed mainly of rocks or metals. It is thought that there could be as many as 40 billion habitable terrestrial planets in the Milky Way alone.

Brown dwarf Teide 1

These objects are larger than planets, but smaller than stars. With a mass in between, they were unable to sustain a nuclear fusion reactor that makes a star, and are sometimes known as 'failed stars'.

Rogue planet WISE 0855-0714

Rogue planets do not orbit their parent star. Instead, they orbit the centre of their galaxy directly, still warmed by their molten cores, but often encased in ice.

62 Neutrons

Neutrons are subatomic particles of neutral charge, and in normal matter they make up part of the atomic nucleus, sitting alongside positively charged protons. Under the immense pressure inside a neutron star however, atoms degenerate and positively charged protons and negatively charged electrons are crammed together so tightly that they too start to form neutrons, making up the bulk of all the matter contained inside.



Outer crust

The outer layer of a neutron star is rigid and incredibly smooth; the tallest 'mountain' on the surface measures just fractions of a centimetre.

Inner crust

The matter inside a neutron star has degenerated, and exists as neutron dense nuclei, alongside free superfluid neutrons and electrons.

Outer core

The matter at the base of the crust is crushed into strange patterns of sheets, rods and spirals, known as 'nuclear pasta'.

Inner core

What lies within the core of a neutron star is unknown, but it could contain exotic particles like unbound quarks.

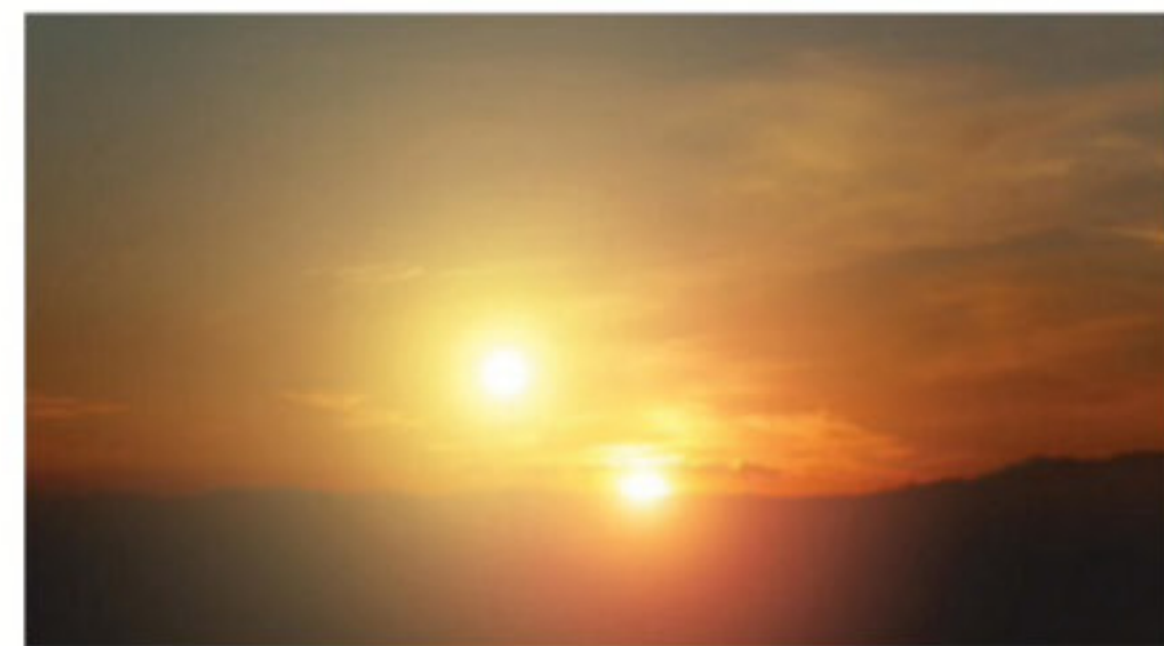
63 Neutron stars

When a massive star runs out of fuel, the outwards explosive force that opposes the inwards crunch of gravity is removed, and in just fractions of a second, the structure collapses. Very large stars collapse entirely to form black holes, but smaller

stars still retain a shred of their former presence in the shape of a neutron star. They are the size of a city, but contain the mass of around 500,000 Earths, and are so dense that a single teaspoonful of their matter would weigh ten million tons.

64 Ant nebula

This object bears a striking resemblance to the head and thorax of an ant, but look closely and a dying star is visible at its core; between the two segments, a star not unlike our Sun is in the midst of collapse. The shape of its explosion has puzzled astronomers, and rather than being uniform in all directions, the gas is wound up into two symmetrical lobes. It is thought that there may be another star, stirring the gas with its gravitational pull, or that the spin of the dying star could be creating these enormous swirls.



65 Twin stars

Around 85 per cent of the stars in the Milky Way are thought to move in pairs, threes, or in larger groups. They are known as binary or multiple star systems, and instead of existing alone, the companions orbit around a common centre of mass. Some pairs can easily be seen through a telescope, while others look like one bright star, but can be distinguished by fluctuations in the colour of their light as they orbit, and some pass in front of one another, producing measurable eclipses that can be seen from Earth.



66 Orion Nebula

The astonishing colours of the Orion Nebula have made it one of the most famous sights in the sky. Just 1,500 light years from the Earth, the glowing red cloud of ionised hydrogen is dominated by a group of three enormous stars collectively known

as the Trapezium. The nebula is just 30,000 years old, and is a place of intense star birth. The hot young Trapezium stars have blown a hollow in their dust shroud, and are illuminating the surrounding cloud.

67 Crab Nebula

This five light year-wide nebula is the remnants of a supernova explosion that lit up the southern sky in 1054 CE. The gas cloud is expanding at a rate of around 1,800 kilometres per second (1,100 miles per second), and the gas creates a glowing rainbow. In the interior, the blue and green filaments are oxygen and sulphur, and towards the edges, the orange and red are hydrogen and oxygen. At the very centre, electrons glow blue as they circle the magnetic field of a neutron star.

68 Whirlpool Galaxy

This near-perfect swirl is a classic example of a spiral galaxy. Like our own galaxy, bright blue stars are formed within the enormous arms, twisting around a central bulge of older orange-red stars in the last phases of their existence. The spirals are lined with dust lanes composed of dark silicon and carbon, and clouds of hydrogen gas glow red as they are excited by the light from the young stars.

69 Space volcanoes

The Solar System is full of volcanic activity. The largest volcano of all, Olympus Mons, is located on Mars, and Venus boasts the highest number of volcanoes of any planet, with over 1,600 major volcanic features, and tens of thousands of smaller volcanoes. Though neither planet has seen recent volcanic activity, it is possible that some are still active. Volcanoes are not just restricted to planets; Jupiter's moon Io is more volcanically active than Earth, and Neptune's moon Triton and Saturn's moon Enceladus both harbour cryovolcanoes, which spew not lava but water. The gravitational pull of the parent planet of each moon warps their shape, causing their internal structure to melt and flex, and resulting in violent eruptions.

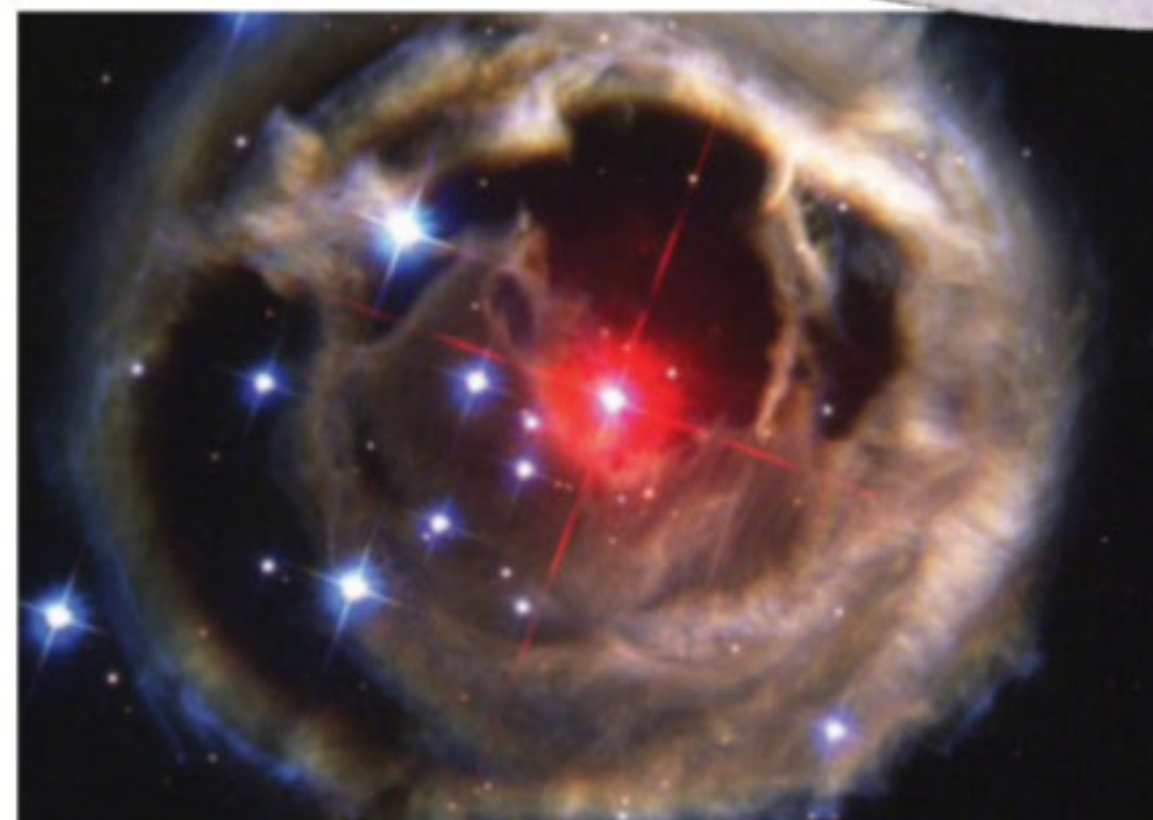
70 Io

Jupiter's third largest moon, Io, is the most volcanically active place in the Solar System, capable of jettisoning lava 300 kilometres (190 miles) into the sky. Its atmosphere is thin and sulphurous, and its surface is constantly being smoothed and remodelled by lava flows. Incredibly, Io acts as a lightning rod, and as it dips through Jupiter's magnetic field it generates currents of up to 3 million amperes, which zip down towards the surface of the gas giant below.

71 Light 'echoes'

In early 2002, the star V838 Monocerotis suddenly became incredibly bright, and then rapidly dimmed again in an unprecedented display that stumped astronomers. During the event, which is known as a 'light echo', the star grew hugely in diameter, but

unlike other ageing stars, it did not lose its outer layers and instead they cooled until its surface was almost cold enough to touch. The light emitted was reflected by dust that the star had already expelled, revealing layers of previously invisible swirls.



72 Globular clusters

These dense symmetrical spheres contain ancient red-orange stars, and are the oldest subsystems inside galaxies, thought to have formed between 13 and 15 billion years ago.

73 Reflection nebula

These nebulae do not emit any light of their own, but they reflect light from nearby stars, revealing their dusty outlines.

74 Asteroid moons

It is not just planets that have satellites, around 16 per cent of large near-Earth asteroids have one, or even two, moons of their own.

75 Cosmic voids

The structure of the universe looks something like a three-dimensional web, with most of the galaxies arranged into clumps and filaments. In between, there are vast holes.

76 Wolf-Rayet stars

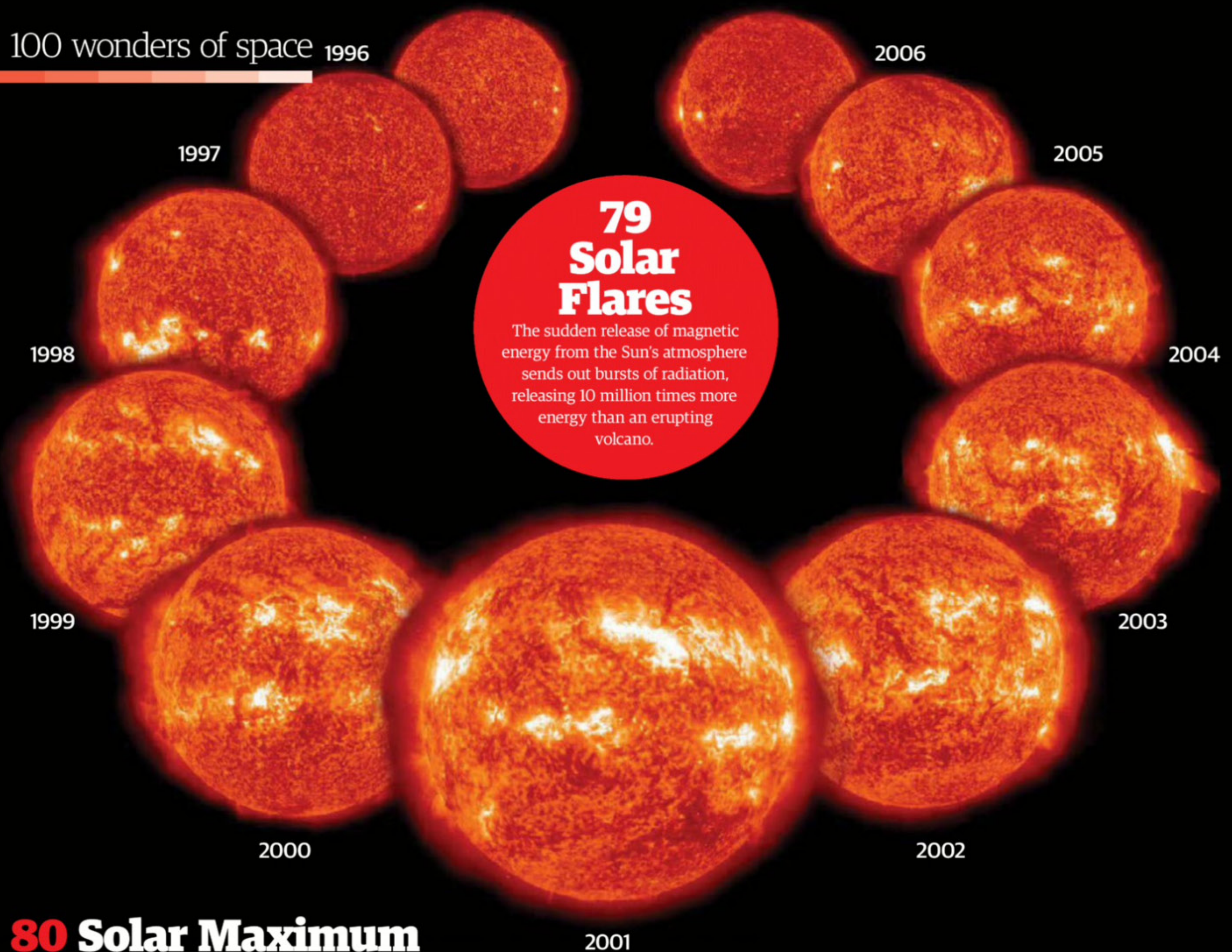
These hot, massive stars are nearing the end of their lives, and have started losing their atmosphere at an astonishing rate as solar winds blow their gases out into space.

77 Ceres

Ceres is the largest object in the asteroid belt; its growth was stunted by the gravity of Jupiter, and at only 950 kilometres (590 miles) across, it is known as an embryonic planet.

78 Large quasar group

The largest structure in the known universe is a cluster of quasars, the violent nuclei of early galaxies, stretching in a chain that covers 4 billion light years.

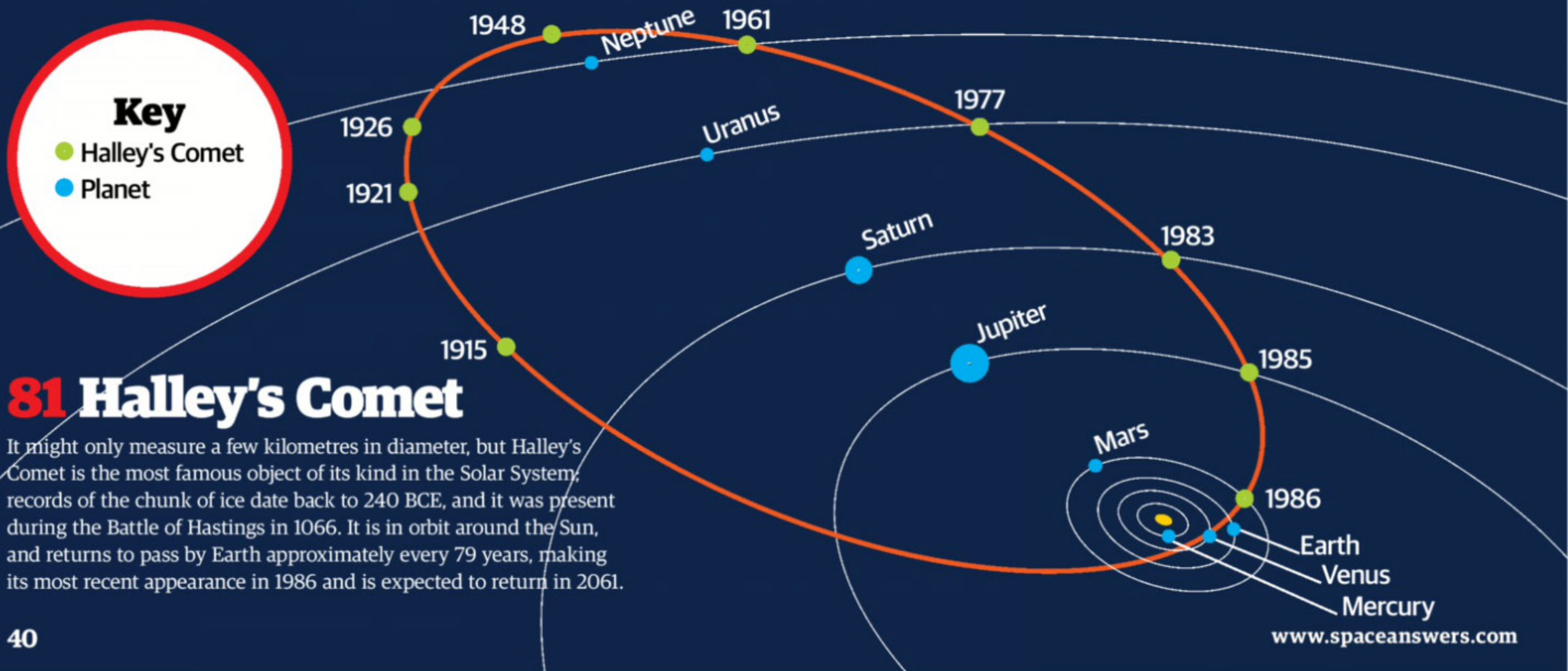


80 Solar Maximum

The Sun is a consistent presence in Earth's sky, but it isn't quite as constant as it might appear. Its magnetic flux varies on an approximately 11-year cycle, and at its peak, known as the solar maximum, sunspots are visible on its surface almost

continuously. In areas where the Sun's magnetic field is at its strongest, the temperature plummets; this creates visible dark spots, some of which can measure 50,000 kilometres (31,000 miles) across. During the solar maximum, the number

of these spots rises, appearing in two bands one either side of the equator, and these active regions are often associated with solar flares and coronal mass ejections, which start to ramp up as the solar maximum passes.





82 Cigar Galaxy

This edge-on spiral is known as a starburst galaxy, and is a hive of star formation activity. The new stars are fuelled by supernovae, and several have been observed over the last few decades. The most recent in the area occurred in 2014.



83 Heart Nebula

A favourite space object on Valentine's Day, IC 1805 bears more than a passing resemblance to a heart. The clouds of dust and gas have been shaped by a cluster of newly formed stars known as Melotte 15, only 1.5 million years old.

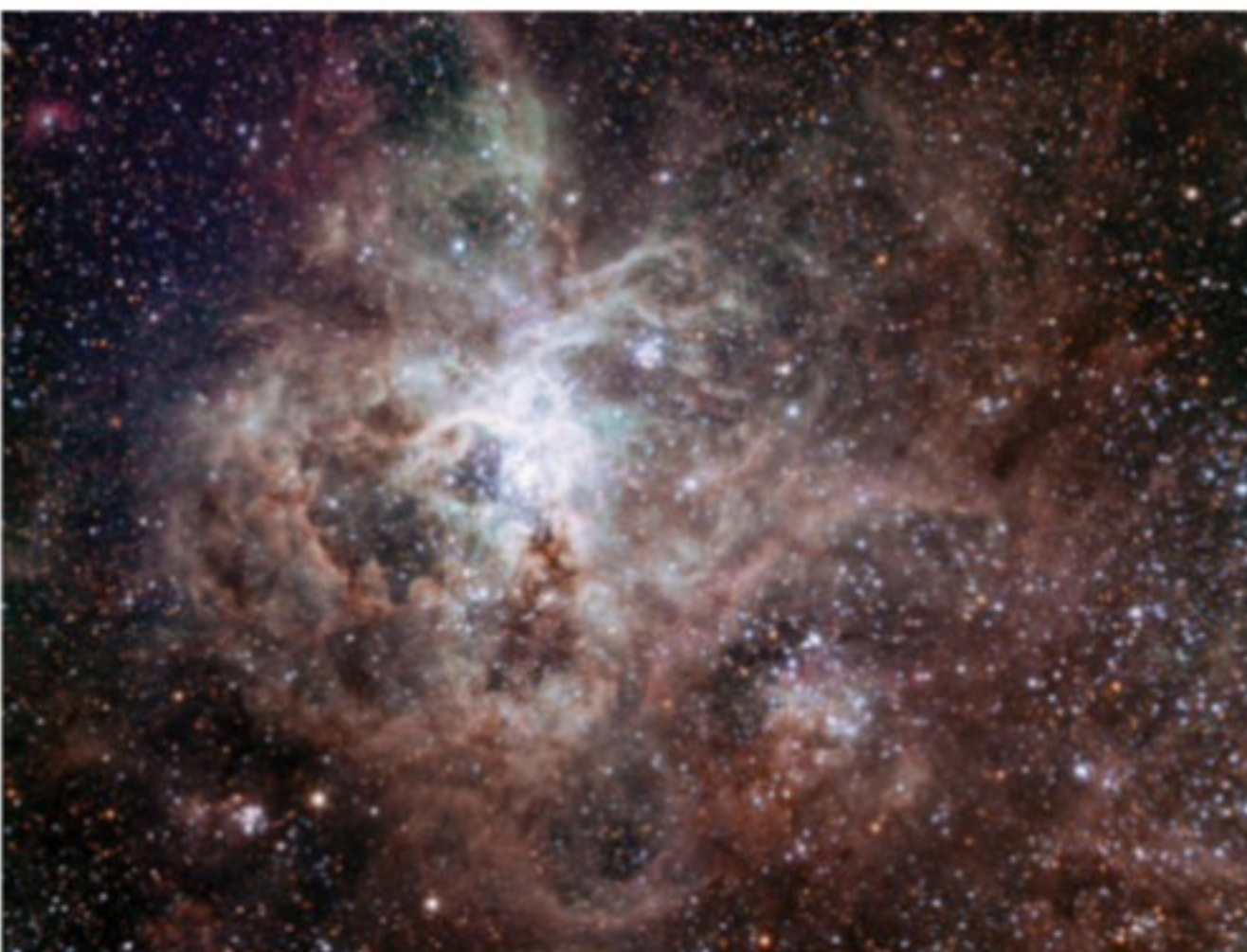


84 Colliding galaxies

The Antennae Galaxies are in the midst of a violent merger. The two galaxies are entwined involved a chaotic dance that began a few hundred million years ago; their dim orange cores are still visible and distinct, but their arms are wrapped together, and bright blue newly formed stars are bursting out of the chaos, lighting up the hydrogen gas in pink.

85 Tarantula Nebula

The wispy arms of the Tarantula Nebula are made from partially ionised hydrogen gas, excited by a supercluster of massive stars called R136. It is the largest star-forming region in nearby space: hidden within it are more than 800,000 new stars. Their energetic activity blows holes in the clouds surrounding them, giving the nebula its lace-like structure.



86 Cartwheel Galaxy

This spiral galaxy suffered a head-on collision that created rings of star formation that rippled out from the centre. Ultraviolet and X-ray light released by new stars and violent black holes are visible in this image as purple and blue, while the green visible light shows the spokes of the cartwheel, revealing clues about the galaxy's shape before the impact.



87 Micro black holes

These hypothetical black holes are thought to have formed early in the history of the universe, and contain the mass of a mountain crammed into the volume of just one atom.

88 Neutrinos

These subatomic particles are made in violent explosions, but with no mass and no charge they can travel through objects, reaching Earth and pointing us back to their source.

89 Hot ice planets

The temperatures on the planet GJ 436b are well above the boiling point of water, but the pressure is so high that it has turned to an exotic form of ice.

90 Dune fields

Despite their differences, Earth, Venus, Mars and Titan all share a common feature; wind in the atmosphere of each has swept the surface dust into rippling dunes.

91 The hole in space

We're located inside a hole in the interstellar medium known as the Local Bubble, formed by a group of exploding supernovae around 10 million years ago.

92 Pole stars

Polaris is the current North Star and is almost lined up with magnetic north, but the Earth's axis spins in a cone-shape every 26,000 years, so this won't always be the case.

93 Rum cloud

Sagittarius 2b, a cloud near the centre of the Milky Way, has 10 billion, billion, billion litres of alcohol, along with a molecule called ethyl formate, which smells like rum.

94 Dinosaur crater

Chicxulub is a 66-million-year-old impact crater in Yucatan, Mexico. It is the site of the asteroid impact that led to the mass extinction event that killed the dinosaurs.

95 Huge canyon

Saturn's moon Tethys is scarred by a 2,000-kilometre (1,200-mile) long canyon called Ithaca Chasma that runs three quarters of the way around its surface. The history behind its formation is unknown, but it is thought that the 100-kilometre (60-mile) wide crack could have formed as the moon cooled, or could have been created during the impact that left the vast Odysseus crater on its leading hemisphere.

97 Painted moon

The surface of Saturn's moon Iapetus is half black and half white, earning it the nickname 'painted moon'. Its strange colouration is thought to be down to debris sprayed onto its face by other moons. As the dark material is heated by the Sun, any ice trapped with it turns to vapour, leaving just the sooty debris behind and preventing the 'paint' being covered with bright ice.

96 Giant river bed

Baltis Vallis is a 6,800-kilometre (4,200-mile) channel on Venus. It is the longest in the Solar System, challenged only by the River Nile in Egypt, which measures around 6,650 kilometres (4,132 miles) from start to finish. At between one and three kilometres (0.6 and 1.8 miles) wide, Baltis Vallis is thought to have been formed by fast-moving lava flows, and resembles a river in the way that it winds across the landscape.

98 Jewel box

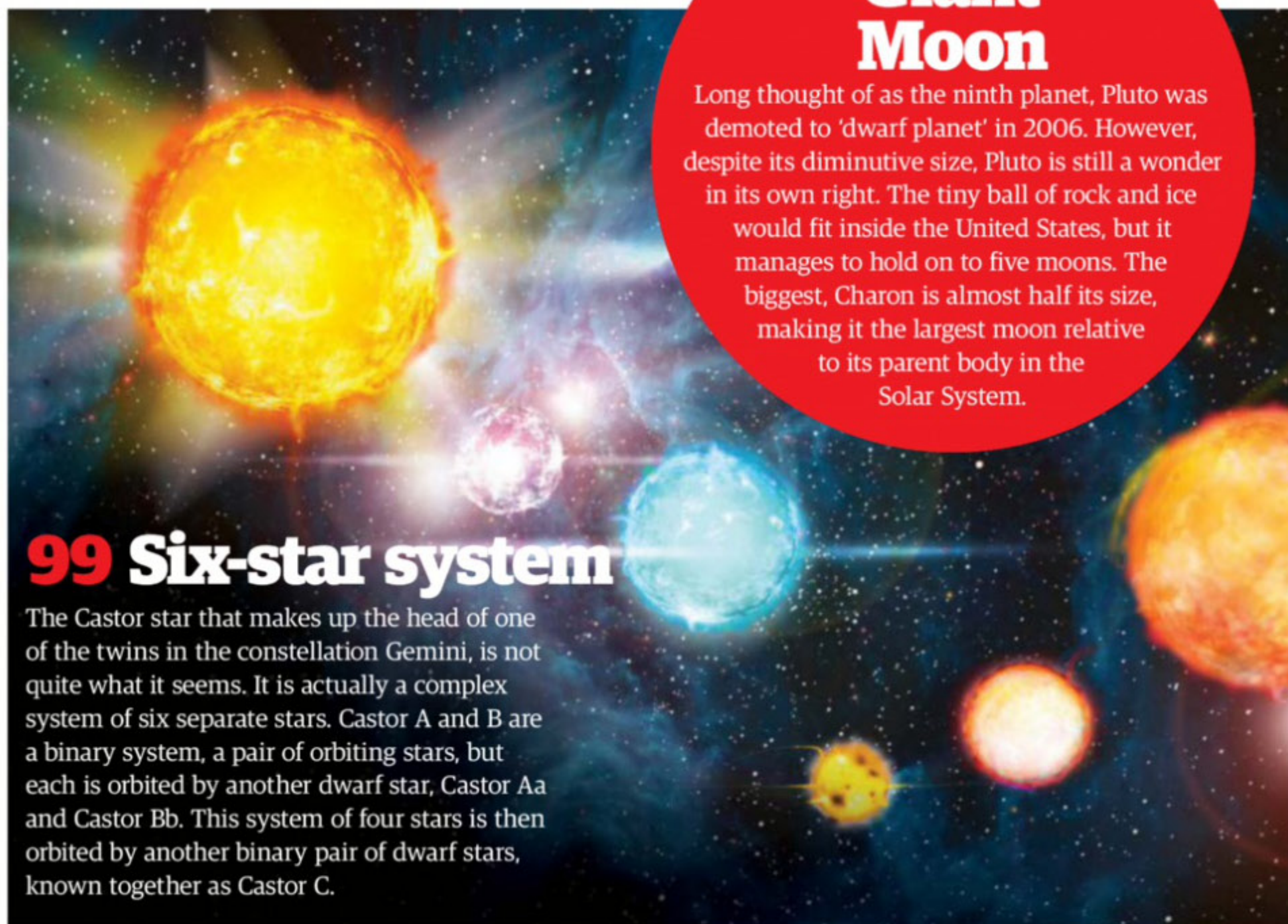
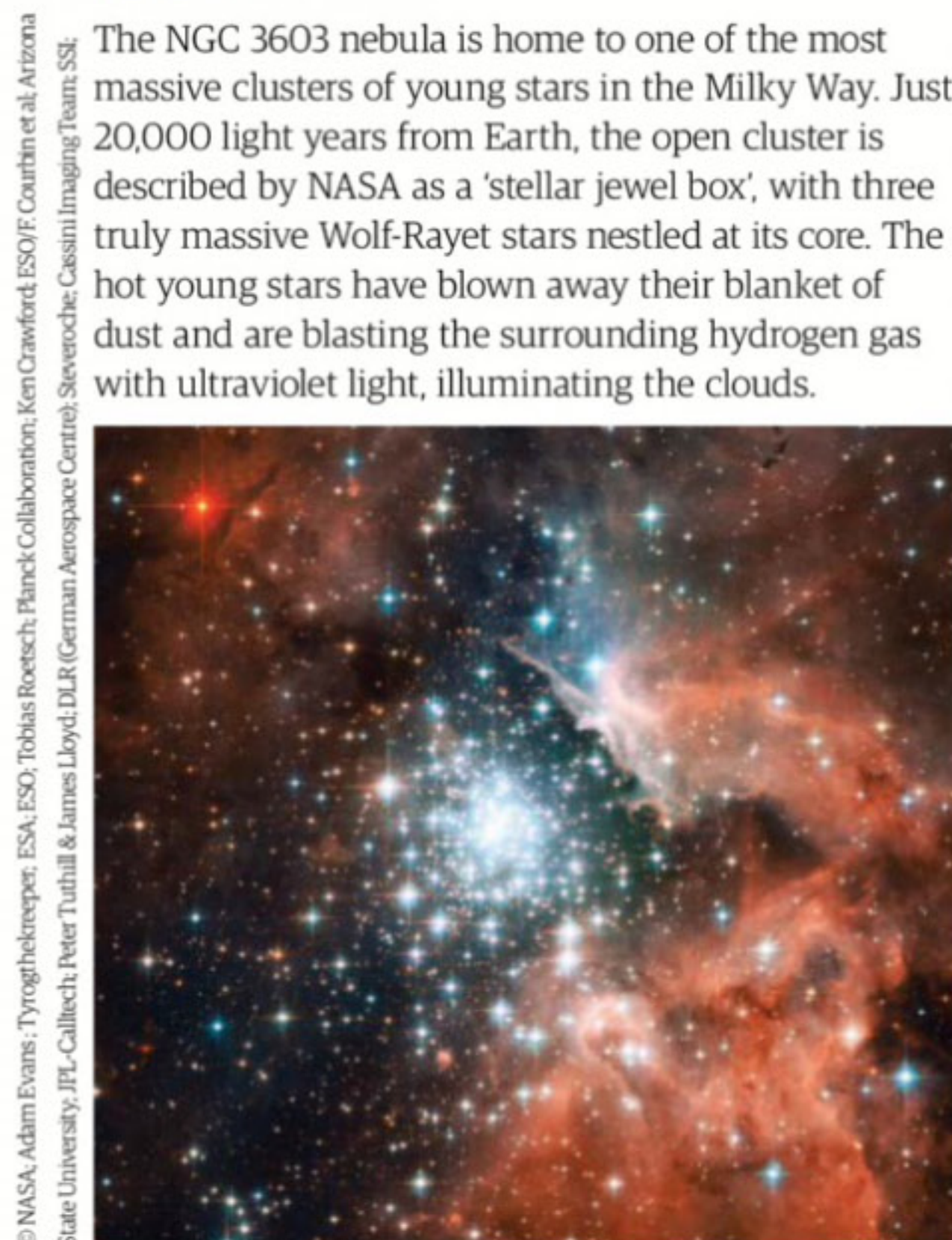
The NGC 3603 nebula is home to one of the most massive clusters of young stars in the Milky Way. Just 20,000 light years from Earth, the open cluster is described by NASA as a 'stellar jewel box', with three truly massive Wolf-Rayet stars nestled at its core. The hot young stars have blown away their blanket of dust and are blasting the surrounding hydrogen gas with ultraviolet light, illuminating the clouds.

99 Six-star system

The Castor star that makes up the head of one of the twins in the constellation Gemini, is not quite what it seems. It is actually a complex system of six separate stars. Castor A and B are a binary system, a pair of orbiting stars, but each is orbited by another dwarf star, Castor Aa and Castor Bb. This system of four stars is then orbited by another binary pair of dwarf stars, known together as Castor C.

100 Giant Moon

Long thought of as the ninth planet, Pluto was demoted to 'dwarf planet' in 2006. However, despite its diminutive size, Pluto is still a wonder in its own right. The tiny ball of rock and ice would fit inside the United States, but it manages to hold on to five moons. The biggest, Charon is almost half its size, making it the largest moon relative to its parent body in the Solar System.



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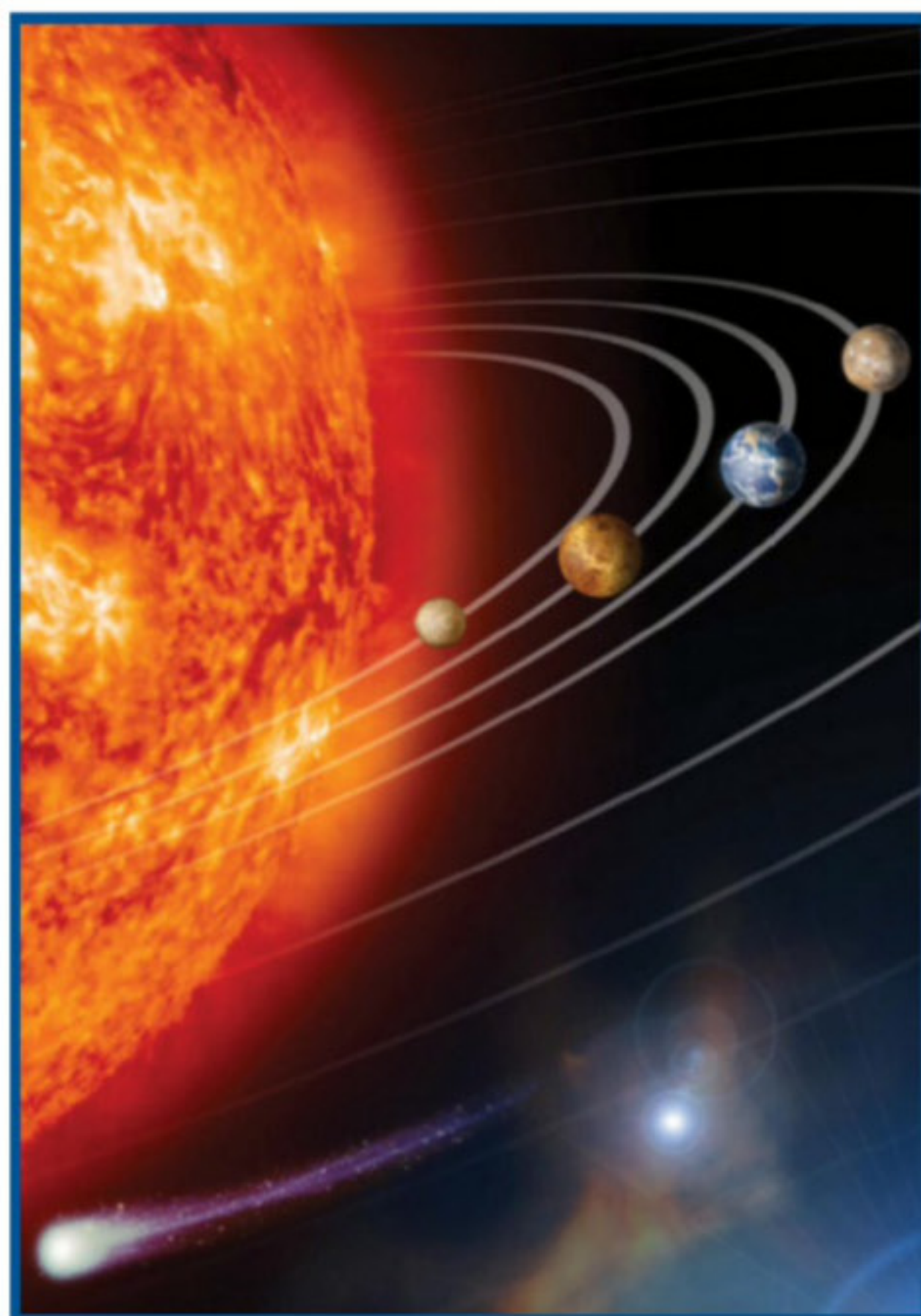
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Asteroid nets

NASA's latest space fishing trip aims to capture an asteroid and bring it closer to Earth to study

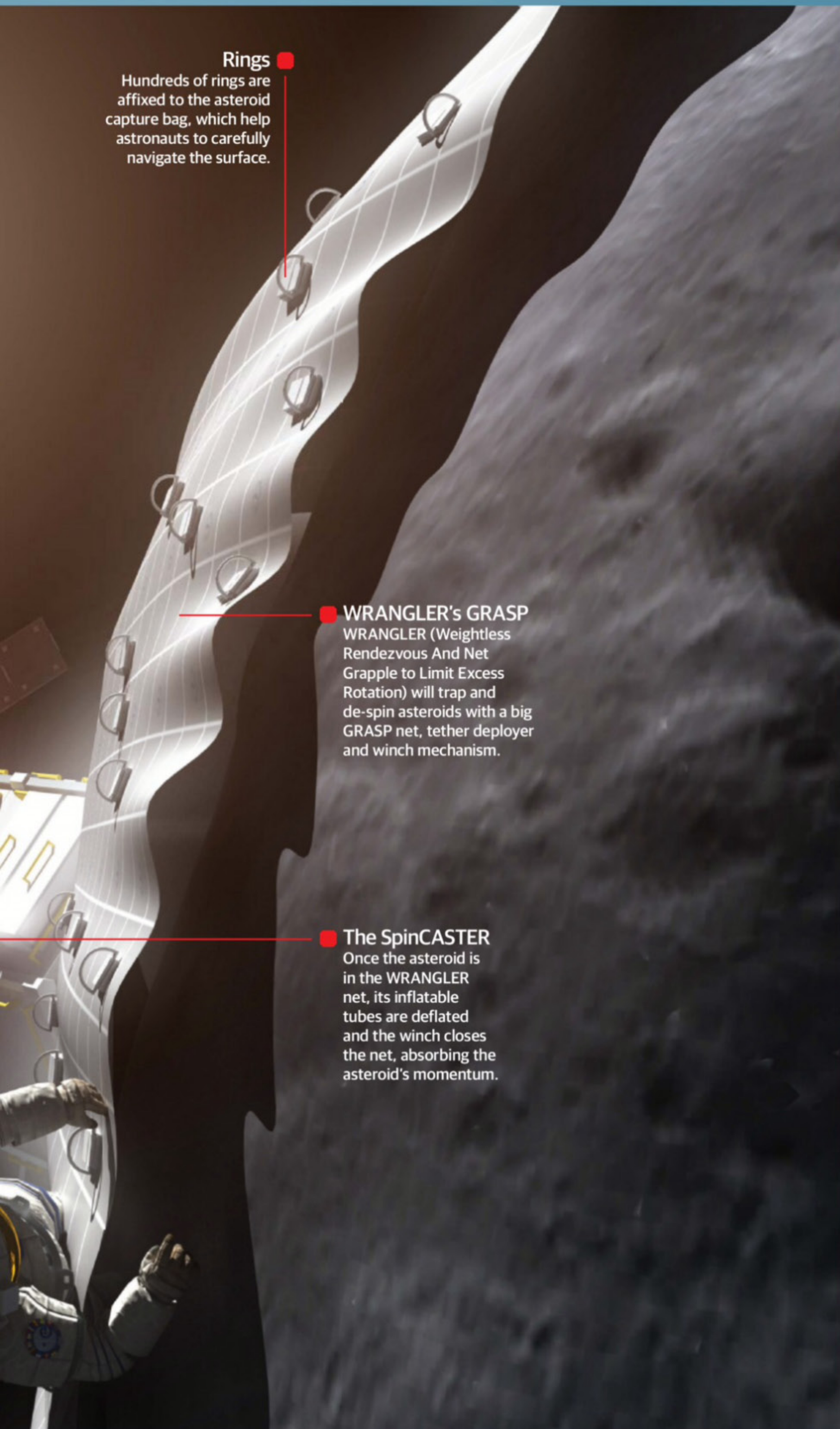
Orion spacecraft
NASA's new spacecraft, which will carry a crew of up to four astronauts in or beyond low Earth orbit - to the asteroids and Mars.

"This mission represents an unprecedented technological feat that will lead to new scientific discoveries"



Asteroid grabber
An alternative concept for a solar-electric-powered spacecraft, with inflatable rings to capture a small near-Earth asteroid.

Astronaut
An astronaut prepares to take samples from the captured asteroid after it has been relocated to a stable orbit in the Earth-Moon system.



Rings

Hundreds of rings are affixed to the asteroid capture bag, which help astronauts to carefully navigate the surface.

WRANGLER's GRASP

WRANGLER (Weightless Rendezvous And Net Grapple to Limit Excess Rotation) will trap and de-spin asteroids with a big GRASP net, tether deployer and winch mechanism.

The SpinCASTER

Once the asteroid is in the WRANGLER net, its inflatable tubes are deflated and the winch closes the net, absorbing the asteroid's momentum.

In June 2010, the Japanese Hayabusa probe succeeded in returning to Earth some dust samples from a distant, stoney asteroid known as 25143 Itokawa. Until now, such missions have rarely been successful because returning samples to Earth is very difficult. But what if the asteroid was closer?

Since 2013, NASA scientists have been working on a plan to identify and capture a small near-Earth asteroid - anything up to about eight metres (26 feet) in diameter - and then redirect it into a stable orbit around the Moon, where it would be accessible to Earth-based astronauts.

Current theories suggest that asteroids are part of the leftover materials from the formation of our Solar System, remaining largely unchanged since then. Having one of these pristine 'time capsules' on our astronomical doorstep would enable far more samples to be returned to Earth. It could potentially lead to numerous new scientific discoveries about the evolution of the Solar System and even the beginning of life on Earth itself.

NASA's Asteroid Redirect Mission (ARM), has begun to identify suitable candidates; in less than two years, NASA's Near-Earth Object Program has already catalogued more than 1,000 new near-Earth asteroids. As of September 2014, three had been confirmed as valid ARM targets.

Although the clever money is on the inelegantly named asteroid 2011 MD - which missed the Earth by about 12,200 kilometres (7,600 miles) back in 2011 - more candidates are likely to be discovered during the next few years, giving NASA experts the best choice possible. The ultimate decision will be informed by factors such as an asteroid's location, speed, orbit, size and rate of spin.

The ARM robotic spacecraft will likely be launched at the end of the decade; NASA is yet to confirm whether it will opt for a scheme using an inflatable system, similar to a bag, to capture a small asteroid complete, or use a robotic arm to snatch a boulder off a much larger asteroid instead.

Critics have pointed out that the manned retrieval of samples is unnecessary, because thousands of meteorites have already been analysed. However, NASA administrator Charles Bolden has insisted: "This mission represents an unprecedented technological feat that will lead to new scientific discoveries and technological capabilities and help protect our home planet."

In addition, scientific offshoots will come from the development and demonstration of space technologies, which will be important to the exploration of Mars. Principle among these is its use of advanced Solar Electric Propulsion (SEP); which create electromagnetic fields to accelerate and expel charged atoms called ions, for very low thrust and efficient use of propellant. Thanks to its SEP system, the ARM mission will use between five and ten times less propellant compared to conventional chemical propellant sources. The mission will provide practical trajectory and navigation experience, comparable to safely landing on Mars.

While the 'asteroid mass' chosen will be of a size and mass sufficiently small to burn up in Earth's atmosphere without causing any harm, ARM will nevertheless demonstrate possible planetary defence techniques to deflect future dangerous asteroids.

Do we live in a multiverse?

Cosmologists are fascinated by the idea that our universe is one among many in a potentially infinite 'multiverse' – but can we ever know for sure?

What exactly is a multiverse? The exact definition depends on which expert you're talking to and which theory you're discussing, but in essence, all hypothetical multiverses are structures that can play host to a large – possibly infinite – number of individual, self-contained universes. A universe, in this context, is simply a volume of four-dimensional space-time, within which uniform laws of physics and fundamental constants of nature apply. Our own universe was created in the Big Bang explosion 13.8 billion years ago and has been expanding ever since. The limited speed of light determines the distance of the furthest objects we can see, creating an 'observable universe' stretching to about 47 billion light years in every direction from Earth, but most astronomers believe that the universe as a whole stretches far beyond this boundary. Traditionally, the Big Bang is seen as creating not just all matter in the universe, but also space and time themselves. It might seem to prevent the creation of a multiverse, but there are several ways in which our universe could still be just one of many.

One possibility lies in the conditions from which the Big Bang arose. Many cosmologists envisage a so-called 'quantum foam' out of which the Big Bang spontaneously erupted. If the same foam could give rise to other Big Bangs, then it could produce large numbers of self-contained, isolated universes, each meeting a different fate depending on its precise mix of physical laws and fundamental constants (as depicted here).

While universes in such a scenario would be forever undetectable from each other, other possible multiverses could leave a detectable imprint. Since the Eighties astronomers have largely accepted a modification of the Big Bang theory called 'inflation', which explains our observable universe as the product of a sudden and dramatic expansion of a tiny portion of the infant universe. Inflation is the only way to create a cosmos with the large-scale features we observe, and may also have helped to determine its physical properties, but some cosmologists have suggested that it might not be a one-off event. Instead, a primordial multiverse might have given rise to an infinite number of inflationary bubbles, each a universe in its own right. The recent discovery of gravitational waves imprinted on the early universe may be an important hint that we live

Big Bang
Universes begin with a Big Bang that may be triggered by a chance fluctuation in the quantum foam (as shown here), or a collision between branes.

in just this kind of multiverse.

However, there are other options. Another possible trigger for the Big Bang is a collision between hypothetical many-dimensional structures known as branes, and if this kind of collision happened once, then it could happen many times to produce many different universes.

And then there are even weirder possibilities. The simulated multiverse theory suggests that we might all exist as one of many *Matrix*-like simulations in an impossibly advanced computer. The quantum multiverse theory, meanwhile, argues that the fuzzy and uncertain events at the subatomic level of matter only create a neatly ordered large-scale cosmos through continuous branching, creating an infinite array of parallel universes in which every possible quantum outcome is played out. Developed in the Fifties, this was the original multiverse theory – it has gained widespread popularity much more recently, but still raises important questions about why we perceive only one universe with a single course of events.

Several other theories have been conjured up from the complexities of theoretical physics, but there's one last theory that's easily grasped – a cyclic multiverse in which individual universes exist not in parallel, but in series. In this scenario, each new universe arises from the ashes of the previous one, creating a cosmic lineage that extends from the infinite past into the infinite future. ●

Big Crunch
Universes that fall back on themselves end in a similar hot, dense state to the Big Bang itself. Some cosmologists speculate that this kind of 'Big Crunch' could give rise to another universe in turn.

Closed universe
The development of an individual universe is determined by fundamental properties such as the strength of gravity and the amount of matter contained within it. If gravity overcomes cosmic expansion, then the universe will eventually collapse back in on itself.

Raw material
The background fabric of the multiverse would lie beyond time and space, perhaps in the form of many-dimensional 'branes', or as an all-pervading 'quantum foam'.

■ Perpetual expansion

In universes like our own, an expansive force called dark energy seems to have grown stronger over time, overwhelming the attraction of gravity to produce an ever-growing cosmos.

■ Perpetual slowdown

If the forces of expansion and contraction are precisely balanced, a universe may expand ever more slowly, but will never come to a halt.

■ Long-lived universe

With less matter and mass, a universe might be able to expand to a huge size and exist for trillions of years before eventually collapsing back.

■ Short-lived universe

Some universes may be so massive that the expanding force of dark energy is never able to take hold, so they rapidly collapse back onto themselves, ending in a 'Big Crunch'.

Evidence for a multiverse?

In March 2014, astronomers using a microwave telescope at the South Pole reported crucial evidence for the early inflation of the universe that may also carry hints that we live in a multiverse. The BICEP2 experiment found telltale curling patterns in the arrangement of rays from the cosmic microwave background - the afterglow of the Big Bang. Analysis of

the BICEP2 results has since shown them to be inconclusive, but these patterns are predicted to have been produced by gravitational waves that rippled across our universe as it underwent expansion. Cosmologists have argued that inflation would almost inevitably lead to a multiverse containing a large number of 'bubble' universes like our own.

The South Pole telescope, Antarctica



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USER MANUAL

Cassini-Huygens

THE SPECS

Launch: 15 October 1997

Launch rocket: Titan IV

Target: Saturn

Operators: NASA, ESA, ASI

Orbital insertion: 1 July 2004

Component: Huygens probe

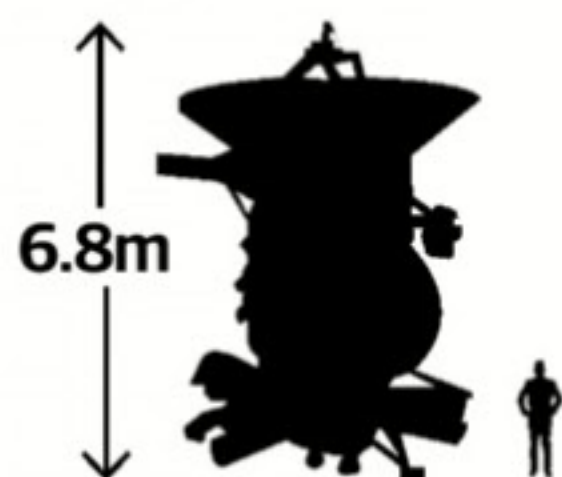
Probe landing: 14 January 2005

Mission ends: 2017

Current time at Saturn:

10 years, 8 months

Flybys: Earth-Moon, Venus, Jupiter



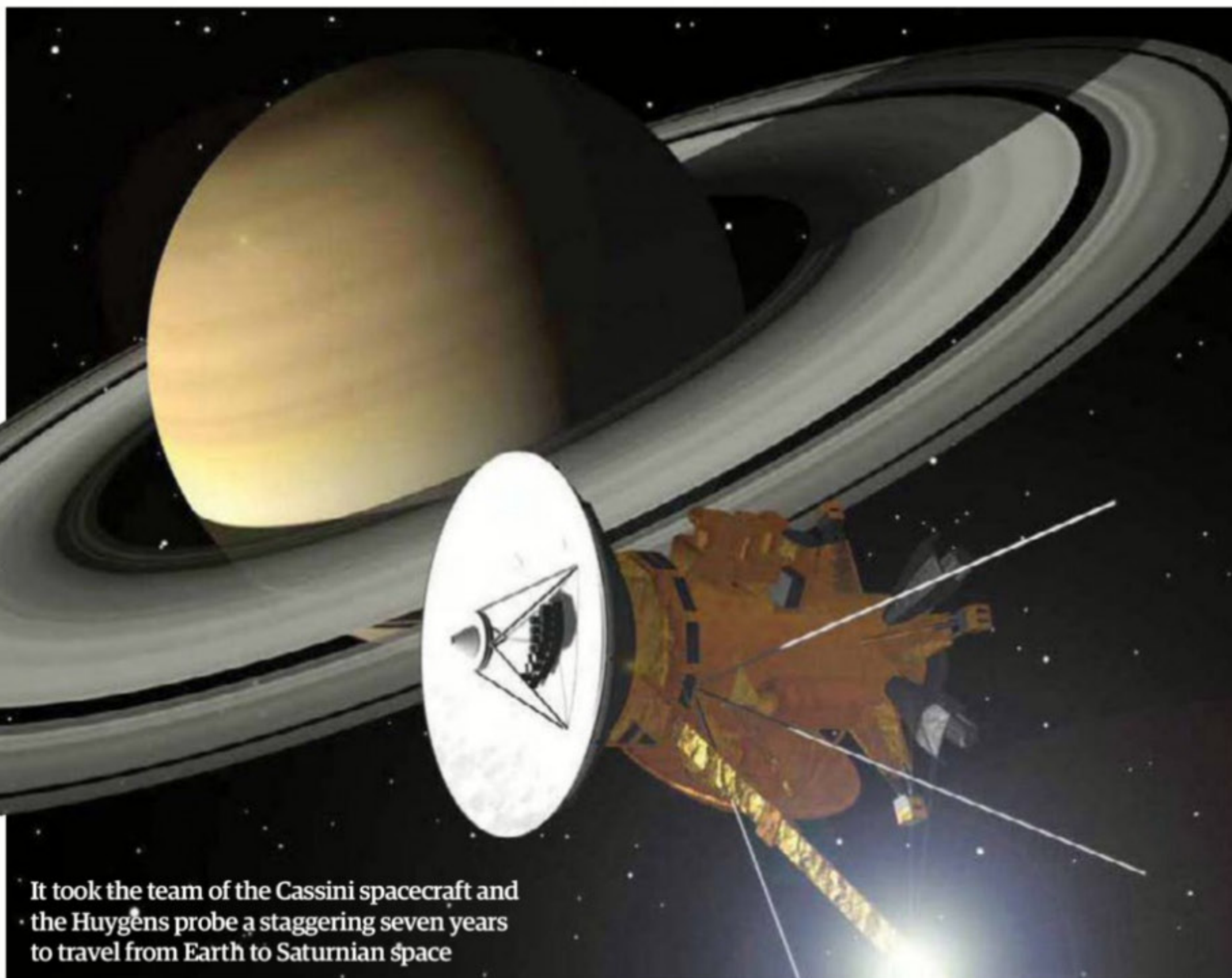
The Cassini spacecraft isn't the first man-made craft to visit Saturn, the ringed gas giant that sits 1.2 billion kilometres (746 million miles) from Earth. That honour goes to Pioneer 11 (for a flyby in 1979), but Cassini has been by far the most influential. For the last decade, the craft and its companion - the Huygens probe that lies on the surface of Saturn's largest moon, Titan - have provided an incredible insight into the composition of a planet 95 times the mass of Earth, and how its unique characteristics affect the 62 natural satellites that orbit it.

Work began on what would become the Cassini project as far back as the early Eighties, but it wasn't until 1988 that the idea of a new mission to Saturn was finally given the greenlight. The mission wouldn't just turn heads for its newly focused cooperation between the two most prolific space agencies in the

world (NASA and the European Space Agency had been more like competitive rivals than co-conspirators in the years before), but because it would also be carrying the ESA-designed Huygens probe all the way to Titan.

With the involvement of 17 different countries, the Cassini-Huygens spacecraft is one of what is known as NASA's 'Flagship' missions - the largest and most expensive of the agency's programmes that have been created to explore the depths of our Solar System. The spacecraft itself launched on 15 October 1997 and began its seven-year journey through our Solar System to Saturn. It arrived in Saturnian space and entered an orbit around the ringed planet on 1 July 2004. From this point Cassini-Huygens began its main four-year mission to study the planet and a year and a half later on 25 December 2005, the

"There's a plan to send the spacecraft into the gas giant planet's crushing atmosphere by September 2017"



It took the team of the Cassini spacecraft and the Huygens probe a staggering seven years to travel from Earth to Saturnian space



Flight mechanics from NASA's Jet Propulsion Laboratory (JPL) lower the Cassini spacecraft on to its launch vehicle adapter

Anatomy of Cassini

As it orbits Saturn, this fascinating spacecraft uses a variety of instruments to unlock the secrets and mysteries of the ringed wonder planet of our Solar System

■ Dual-Technique Magnetometer

Otherwise known as the MAG, this instrument is essentially a sophisticated compass that enables Cassini to measure the magnetic fields of Saturn and its moons.

■ Visible and Infrared Mapping Spectrometer

The VIMS serves two roles with a duo of cameras: the first of its lenses measures visible wavelengths while the other detects invisible infrared ones.

■ Radio and Plasma Wave Spectrometer

This antenna detects radio waves coming directly from Saturn, as well as the radio waves caused by the collision of solar winds between Saturn and Titan.

■ Imaging Science Subsystem

The ISS serves as the eyes of the Cassini spacecraft. It consists of two cameras – one with a wide-angle lens, the other with a narrow-angle lens – and captures incredible HD images.

■ Composite Infrared Spectrometer

Cassini's CIRS system provides the ability to detect heat changes in the atmosphere of Saturn and its moons. It's also ideal for understanding unusual weather patterns.

■ Radar Bay

By detecting and measuring the behaviour of microwaves, the Radar Bay (along with the large antenna at the top) can determine what a planet or moon's landscape looks like.

■ Ion and Neutral Mass Spectrometer

The INMS is vitally important to the data Cassini collects as it detects the composition and structure of positive ions and neutral particles.

■ Cassini Plasma Spectrometer

This instrument (commonly referred to as CAPS) measures the electrical charge and energy of the particles that the other instruments detect, such as protons and electrons.

■ Magnetospheric Imaging Instrument

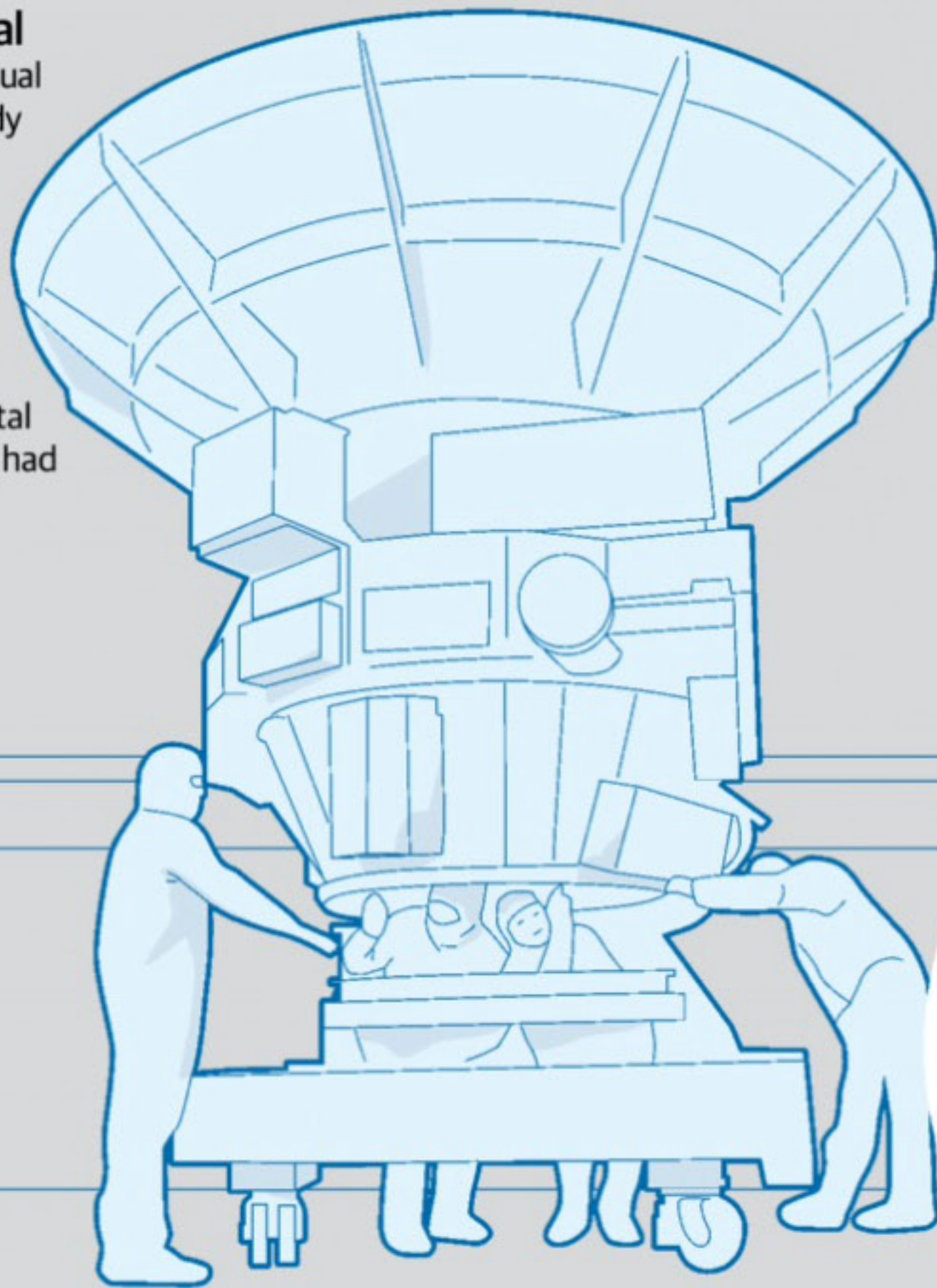
The MIMI serves three functions: measuring the activity of energetic ions and electrons, detecting fast neutrons and remote imaging Saturn's magnetosphere.

■ Ultraviolet Imaging Spectrograph

Cassini's on-board UVIS is a box containing four individual cameras designed to detect ultraviolet light on Saturn and its many orbiting moons.

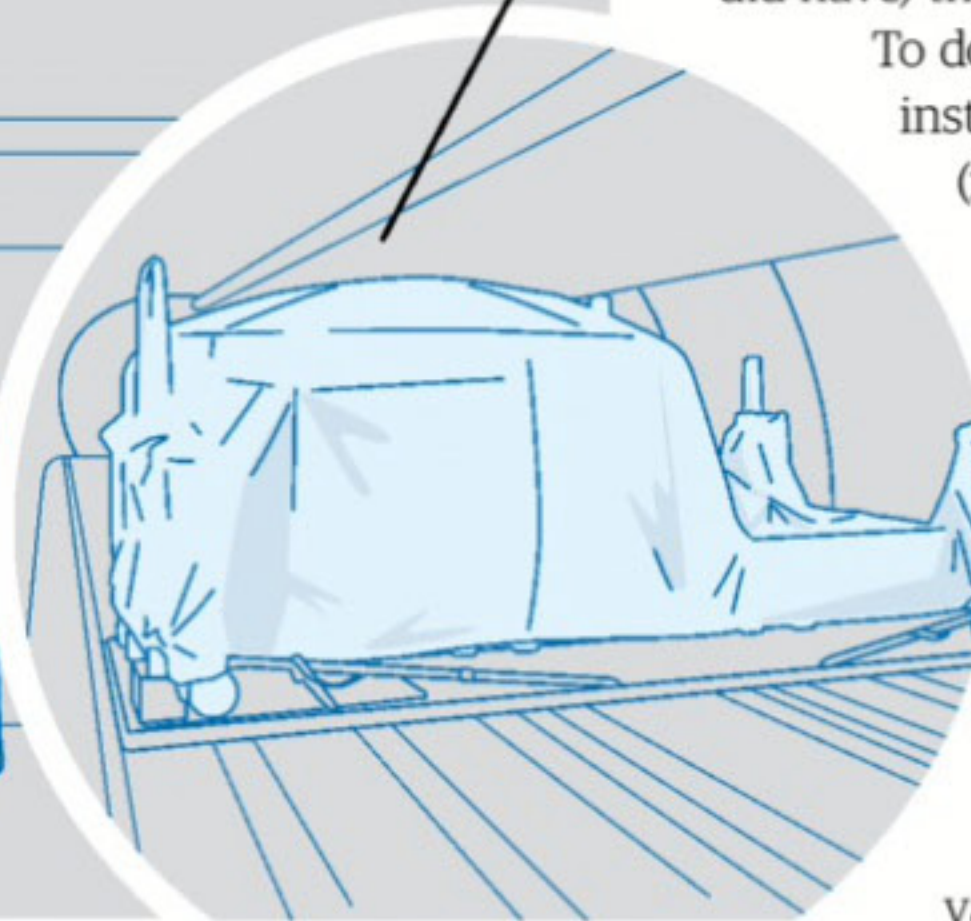
International

The idea of a dual mission to study Saturn and its largest moon Titan was suggested as early as 1982. By the time of its launch, a total of 17 countries had contributed to its design.



Lander

The Huygens Descent Module, which includes the probe itself, three separate parachutes and a heat shield was initially tested in a snowy Sweden in 1995.



Huygens probe was released into the atmosphere of nearby moon, Titan.

So what are Cassini and Huygens actually doing during their stay? Cassini has a far broader range of missions, but the main ones include determining the structure and size of the rings that surround Saturn, studying the atmosphere of the planet itself, examining the surface of each of its many natural satellites as well as the history of each one (to name but a few). Huygens was the first man-made lander to touch down successfully on a moon beyond our own and its goals include determining the chemical elements found in Titan's atmosphere, whether or not Titan has any oceans and whether it has (or ever did have) the potential to support life.

To do this, the duo use 18 separate instruments - 12 are used on board Cassini (including a magnetometer for testing magnetic fields and a device that measures cosmic dust), while the Huygens probe uses a more modest set of six (such as an Aerosol Collector for gathering dust samples and a Doppler Wind Experiment that uses radio waves to test the composition of the atmosphere). Together these two spacecraft have gathered and beamed back reams of valuable data on Saturn and Titan.

Huygens' journey to Titan

■ Separating from Cassini

On December 25, 2004, the Huygens probe detaches from Cassini into the atmosphere of Saturn's largest moon, Titan. It's a descent that will last 22 days.

■ Gathering data

As it passes through the atmosphere of Titan, the probe's instruments power into life and begin gathering data.

■ Releasing the heat shield

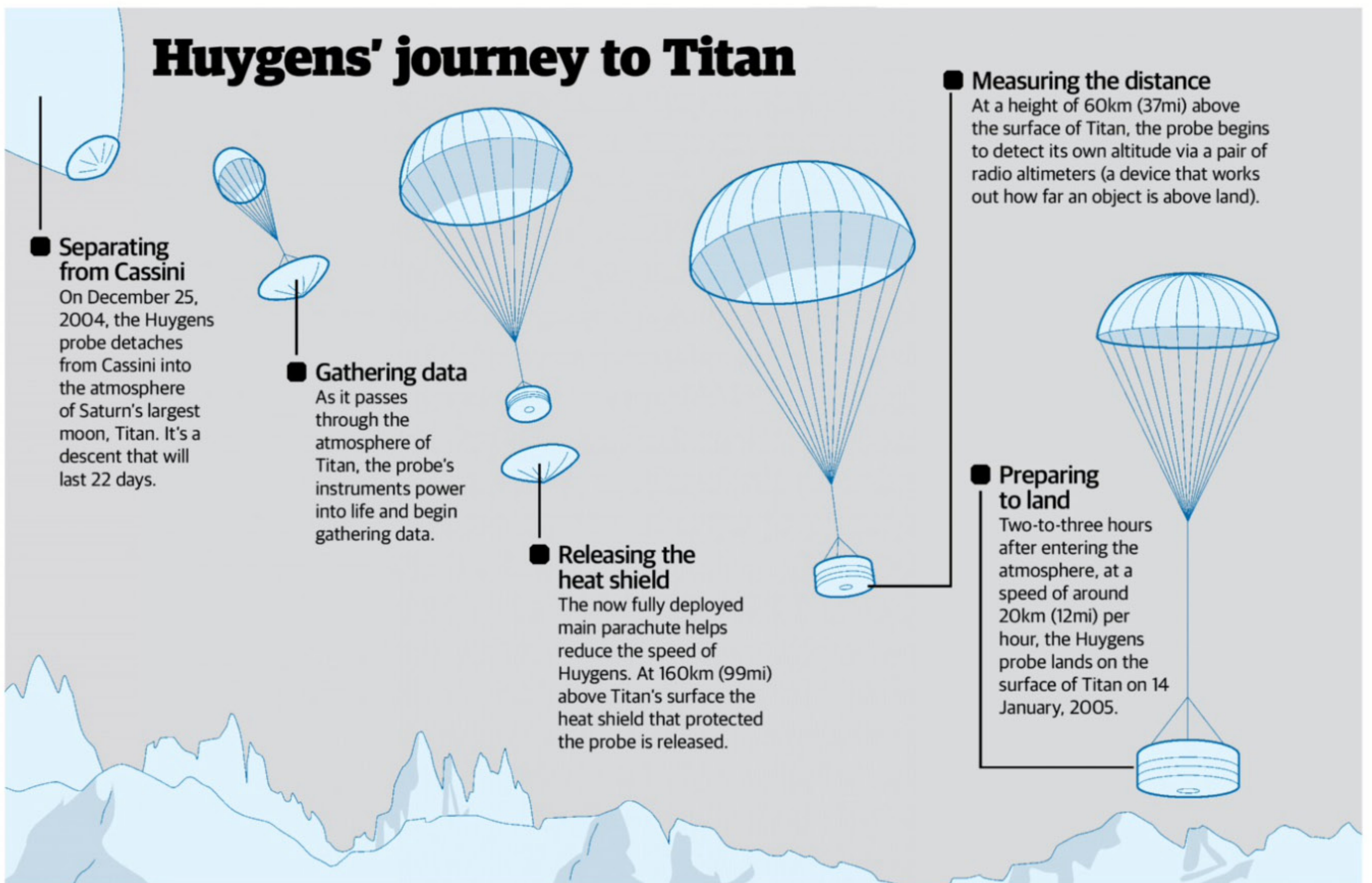
The now fully deployed main parachute helps reduce the speed of Huygens. At 160km (99mi) above Titan's surface the heat shield that protected the probe is released.

■ Measuring the distance

At a height of 60km (37mi) above the surface of Titan, the probe begins to detect its own altitude via a pair of radio altimeters (a device that works out how far an object is above land).

■ Preparing to land

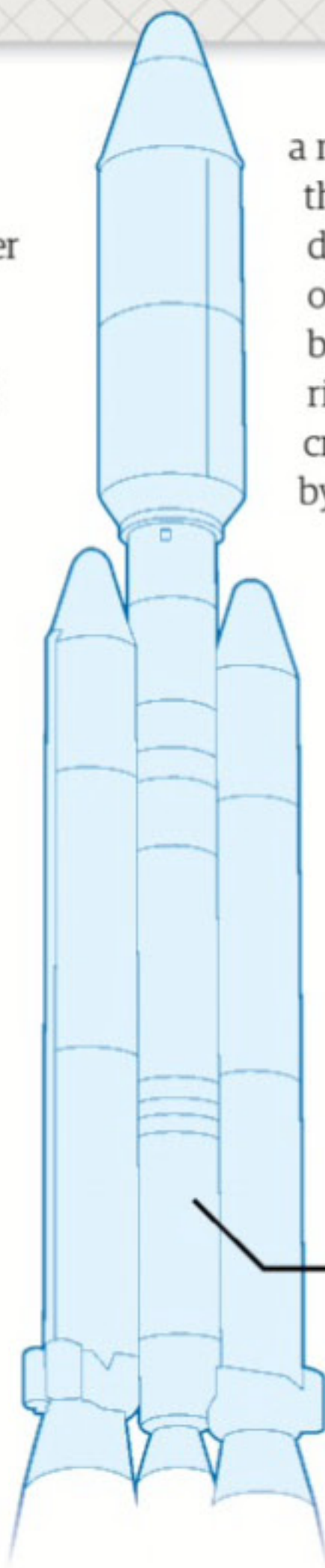
Two-to-three hours after entering the atmosphere, at a speed of around 20km (12mi) per hour, the Huygens probe lands on the surface of Titan on 14 January, 2005.



At approximately 2,125 kilograms (4,685 pounds), and with all those instruments on board, it takes a great deal of energy to power Cassini. So how does it do it? It uses three devices called Radioisotope Thermoelectric Generators, contraptions that work like mini engines, converting the energy given off by decaying plutonium and converting it into rather useful electricity. Just 30 kilograms (66 pounds) of plutonium pellets provided Cassini with more than enough juice to complete its primary mission.

Cassini wrapped up its main four-year mission in 2008, before beginning a new one in the form of the Equinox project. Focused on flybys (quick passes) of many of Saturn's satellites, the two-year mission lasted until 2010 when it began its third mission, Solstice. Due to run through until Cassini's retirement in September 2017, this celestial swansong will study the effects of the Sun reaching its highest point on the northern hemisphere of Saturn. It will also observe how this corner of space changes over the course of seven years.

So, with ten years under its belt orbiting Saturn, what's next for this flagship spacecraft? NASA has considered



a number of plans for the eventual retirement of the craft, but thankfully the agency has finally decided on an endgame for Cassini. The 17-year-old craft will begin a series of super-tight orbits between Saturn's atmosphere and its innermost ring in late 2016, with a plan to steer it into the crushing pressure of the gas giant's atmosphere by September 2017.

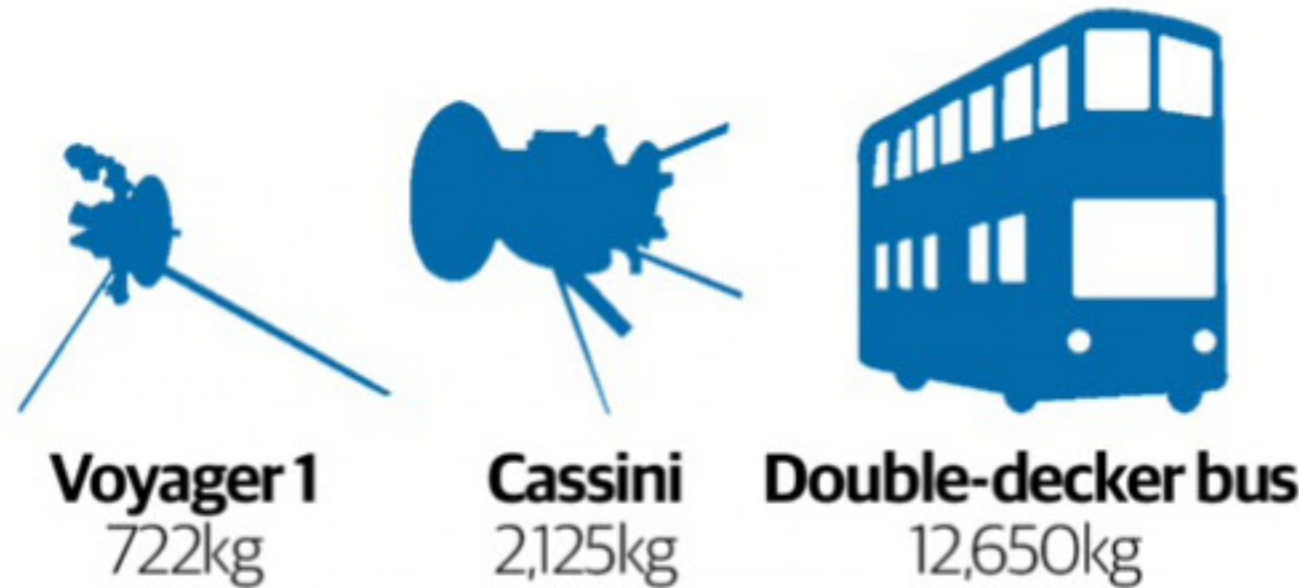
But why terminate the spacecraft's mission by sending it into the deadly atmosphere of Saturn rather than letting it drift off into the cold embrace of space? It all comes down to conservation in space: while there's no proof that life exists on Titan and its fellow Saturnian satellites, NASA would rather preserve the safety of potential indigenous life forms by guaranteeing Cassini's fate. While it may seem like a waste to destroy Cassini in such a way, there's an undeniable sense of poetic finality knowing this flagship vehicle will end its mission in the heart of the very planet it has spent so long studying.

Heavy lifting

At launch, the Cassini spacecraft stood an incredible two stories tall and weighed 5,300kg (11,680lb). Interestingly, over half of this weight was the fuel needed to get Cassini to Saturn.

Head to head

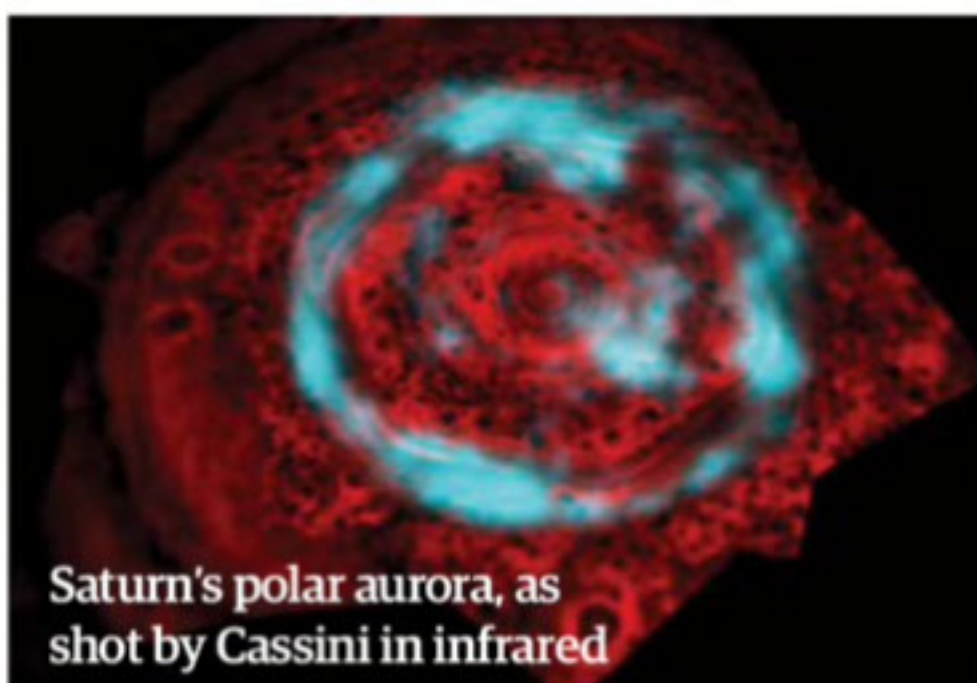
Compared to most other spacecraft, Cassini was a heavyweight, weighing over five tons at launch. Without the Huygens probe and the fuel it needed, it was half its original weight. Voyager 1 studied Saturn too and weighed a third of that.



TOP TECH

Cassini's infrared eyes

Cassini has provided invaluable images and data regarding Saturn and its many satellites. One of the most important of its 12 instruments is the Composite Infrared Spectrometer (CIRS). It reads planetary bodies around it like a snake's tongue tests the air, checking for heat signatures. It's vital for determining atmospheric composition and how hot a planet or moon is.



Saturn's polar aurora, as shot by Cassini in infrared

Vital statistics

2 BILLION Miles travelled 2004-2014 = **8** Around Earth times

206 Saturn orbits completed = **17 YEARS** worth of lunar orbits

332,000 Images taken of Saturn and its 62 moons = **5,270** photos per object

514 GB of data collected = **110** DVDs

HOW TO...

Navigate Cassini

1 Determine its range

Uplink coded signals to the spacecraft and use the Deep Space Network to record both the precise time that Cassini receives them, then when Earth receives the spacecraft's response. Use this time difference to calculate its distance from Earth.



2 Discover its position

Take some images of the background stars with Cassini's cameras. Use these images to precisely determine its location and where Saturn's moons and rings are found relative to Cassini's position.



3 Flight path adjustments

Now you have both Cassini's distance from Earth and location, you can send manoeuvre commands to fine-tune its flight path and velocity (delta-V) if the spacecraft is heading off-course.





Stephen Hawking's theoretical work on black holes, the Big Bang and space-time have revolutionised our understanding of the universe

Professor Stephen Hawking and the beginning of time and space

Hawking talks about how the cosmos began and whether or not our universe is nothing more than a hologram

Interviewed by Gemma Lavender



INTERVIEW BIO

Professor Stephen Hawking

An English theoretical physicist, cosmologist and director of research at Cambridge University's Centre for Theoretical Cosmology, Professor Stephen Hawking has achieved success in popular science as the author of *A Brief History Of Time* and scientific research where he, along with physicist Roger Penrose, predicted that black holes emit radiation.

Immediately after the Big Bang, the universe expanded rapidly in a process called inflation. Could you explain what inflation is?

The world record for inflation was in Germany after the First World War. Prices rose by a factor of 10 million in a period of 18 months, but that was nothing compared to the inflation in the early universe. The universe expanded by a factor of a million, trillion, trillion in a tiny fraction of a second. Unlike the inflation in prices, the inflation in the early universe was a very good thing. It produced a very large and very uniform universe, just as we observe.

Although inflation produces a universe that is nearly the same everywhere, and in every direction, there will be local irregularities produced by quantum fluctuations [these are temporary changes in the amount of energy at a particular point in space]. Permutations [or order] in the universe come in two kinds: those that correspond to variations in the density and rate of expansion, and those that correspond to gravitational waves [ripples in the curvature of space-time]. Both of these kinds have a common cause. This is basically the same mechanism as so-called Hawking radiation from a black hole horizon, which I predicted some time ago.

Was there anything before the Big Bang?

In the early Sixties there was a big debate as to whether the universe had a beginning a finite time ago. And so, the obvious question was, what happened before the beginning of the universe? As Saint Augustine [an early

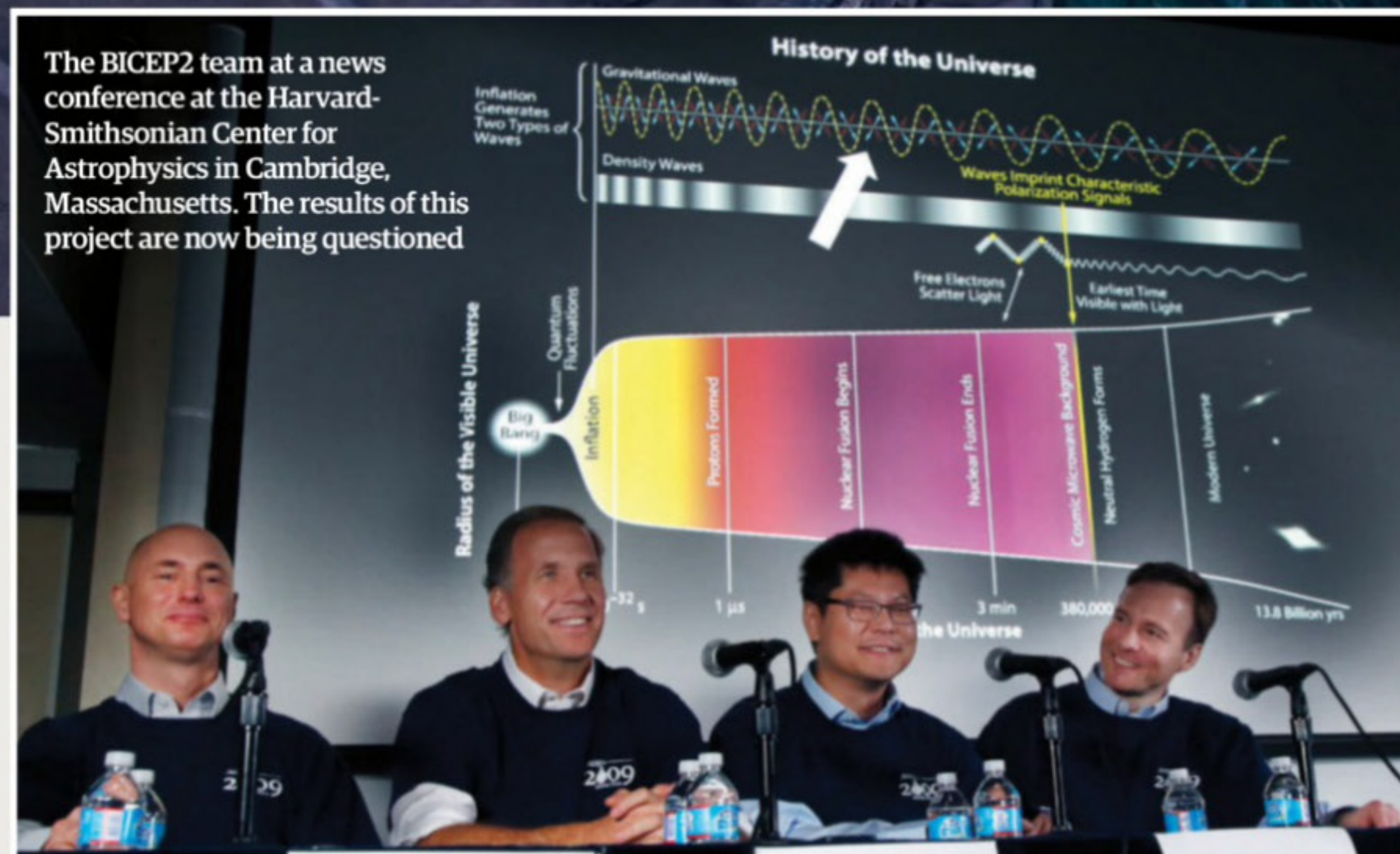
philosopher] said, what was God doing before he made the universe? He was preparing for all the people who asked such questions!

Does it require a creator to explain how the universe began, or is the initial state of the universe interpreted by a law of science? To answer how the histories of the universe began, Jim Hartle [a professor of physics at the University of California, Santa Barbara] and I proposed what we called the 'no-boundary hypothesis'. The problem of what happened at the beginning of time is a bit like the question of what happened at the end of the world when people thought the world was flat. Is the world a flat plate with a sea going over the end? I have tested this experimentally. I have been around the world, and I have not fallen off!

As we know, the problem of what happens at the end of the world was solved when people realised the world was not a flat plate, but a curved surface. One can think of the Earth's surface as beginning at the South Pole, as you head northwards the size of the circles of latitude increase. According to the no-boundary hypothesis, the history of the universe is like this. The history begins at a single point at the South Pole. To ask what happened before the beginning of the universe would become a meaningless question because there is nothing south of the South Pole. Imaginary time, as measured in degrees of latitude, would have a beginning at the South Pole, but the South Pole is like any other point. The same laws of nature hold at the South Pole as in other places. This would prove the age-old objection to the universe

Interview Professor Stephen Hawking

The BICEP2 telescope (foreground) in Antarctica, shown with the South Pole Telescope, supposedly collected evidence of gravitational waves (ripples in space-time from the early universe)



having a beginning and that it would be a place where the normal laws broke down. The beginning of the universe would be governed by the laws of science, such as quantum gravity that merges the theories of quantum mechanics - the science of very small things such as particles - with the theory of gravity, which acts over large distances.

So how do we think the universe began?

The universe must have at its beginning a singularity.

A singularity is a place where the [solutions to the] field equations of classical general relativity can't be found. So classical general relativity cannot predict when the universe began.

This was a conclusion with which Pope John Paul was happy! At a conference on cosmology at the Vatican, the Pope told cosmologists that it was okay to study the universe after it began, but they should not inquire into the beginning itself, because that was the moment of creation and the work of God. I was glad he didn't realise

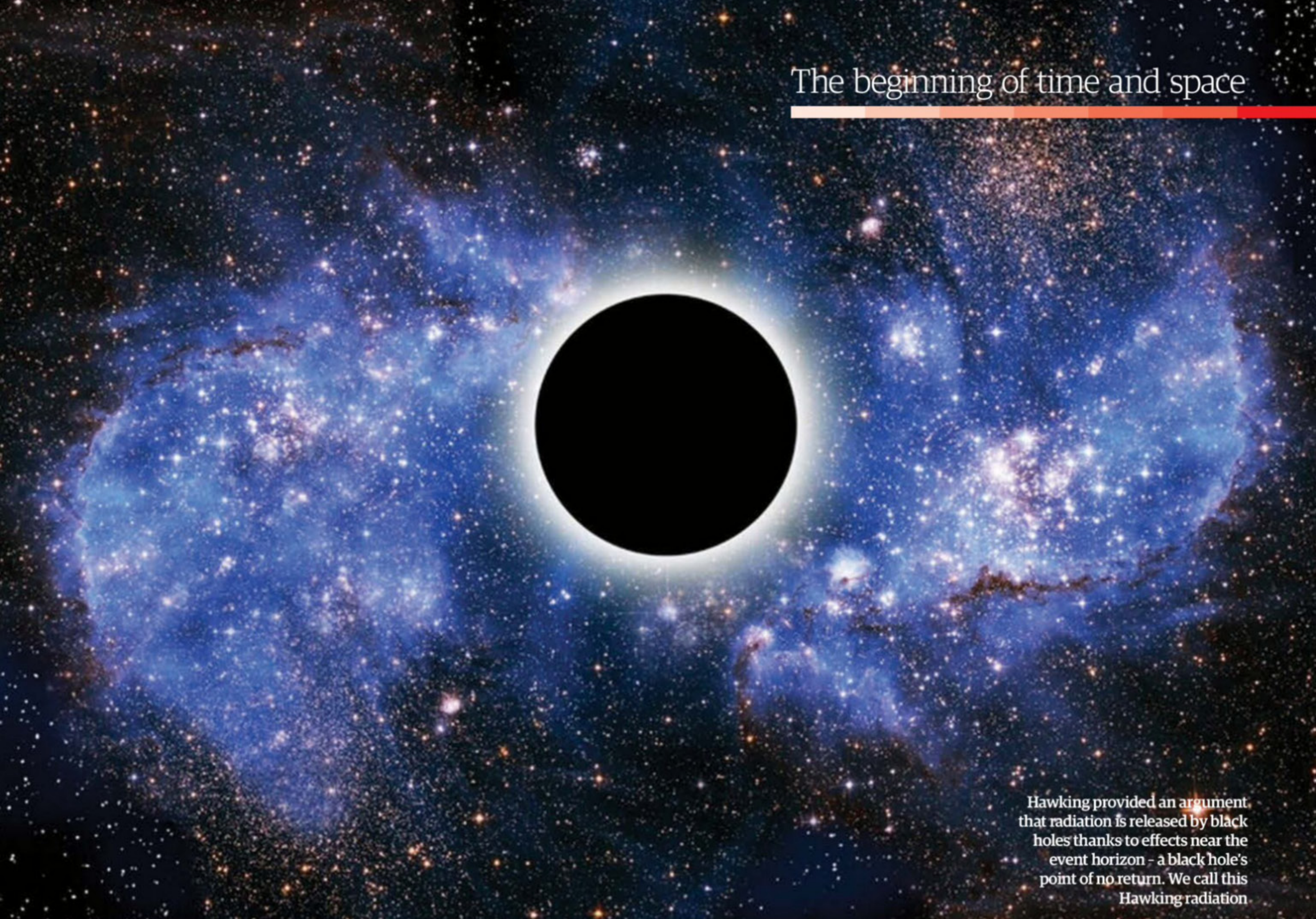
"I was playing poker with Albert Einstein, Isaac Newton and Commander Data on the Holodeck"

I had given a paper at the conference suggesting how the universe began. I didn't fancy being handed over to the Inquisition like Galileo!

Many modern cosmologists are like Pope John Paul. They are happy to apply the laws of physics to the universe after it actually began, but they evade the actual beginning. But in one sense cosmology has no predictive power over what happened at the beginning of the universe. All it can say is that things are as they are now because things were as they were shortly after the beginning. Although classical general relativity predicts that the beginning of the universe was a singularity, at which the theory breaks down, we know that theory has to be quantised like the theories of all other physical fields. Although we don't yet have a complete theory of quantum gravity, that is how it all works, we have an approximation that is good for practical purposes.

Has the Big Bang always been the preferred theory?

The prevailing theory used to be that the universe had lasted forever, because something eternal was more perfect, and because that avoided all the questions about the creation. In order to avoid the universe having a beginning, astronomer Fred Hoyle proposed the 'Steady State' theory. In this theory, the universe will have existed forever with new matter being continually created as the universe expanded, to keep the density the same. The Steady State theory was never backed up by observation, and had an energy field that was objectionable to particle physicists because it would lead



Hawking provided an argument that radiation is released by black holes thanks to effects near the event horizon - a black hole's point of no return. We call this Hawking radiation

to runaway production of pairs of positive and negative energy particles. But the final nail in the coffin came with the discovery of a faint background of microwaves. These microwaves are the same as those in your microwave oven, but much less powerful - they would heat your pizza only to -271.3 degrees Celsius [-456.34 degrees Fahrenheit]. That's not much good for defrosting a pizza, let alone cooking it. You can observe this yourself by setting your analogue TV to an empty channel. A few per cent of the 'snow' that you see on the screen will be caused by the microwaves.



With Jim Hartle, Hawking proposed that there was nothing - not even time - before the Big Bang

There was no way the Steady State theory could account for this background. A reasonable interpretation of the background is that the radiation is left over from an early, very hot and dense state - the Big Bang. As the universe expanded, the radiation would have cooled until it was just the faint relic we observe today.

You have described the universe as a hologram. What does this mean?

The universe has three spatial dimensions plus time, so it is a four-dimensional object that can therefore be represented as a hologram on a three-dimensional surface. The history of the universe can be represented as a hologram on the boundary of a four-dimensional disc.

As I expect you know, a hologram is a representation of a three-dimensional object on a two-dimensional surface such as a photographic plate. I was supposedly represented as a hologram in an episode of *Star Trek: The Next Generation*. I say supposedly because although I may have appeared three-dimensional on the Starship Enterprise, television sets at the time could not, and still can't, display three-dimensional holographic images. That will be the next technological revolution. In the episode I was playing poker with Albert Einstein, Isaac Newton and Commander Data [on the Holodeck]. Because the game was interrupted by a red alert on the Enterprise, I couldn't cash in my winnings of 140 Federation credits. I approached Paramount Studios, but they did not know the exchange rate!

What can the cosmic microwave background radiation tell us about the universe?

Cosmology became a precision science in 2003 with the first results from the Wilkinson Microwave Anisotropy Probe (WMAP) satellite, which confirmed our simplest predictions of cosmic inflation. WMAP produced a wonderful map of the temperature of the cosmic microwave background, a snapshot of the universe at about three hundred-thousandths of its present age. The irregularities that we see are predicted by inflation and they mean that some regions of the universe had slightly higher density than others. The gravitational attraction of the extra density slows the expansion of that region and can eventually cause it to collapse and form galaxies and stars. So look carefully at the map of the microwave sky and it is the blueprint for all the structure in the universe. We are the product of quantum fluctuations in the very early universe. God really does play dice.

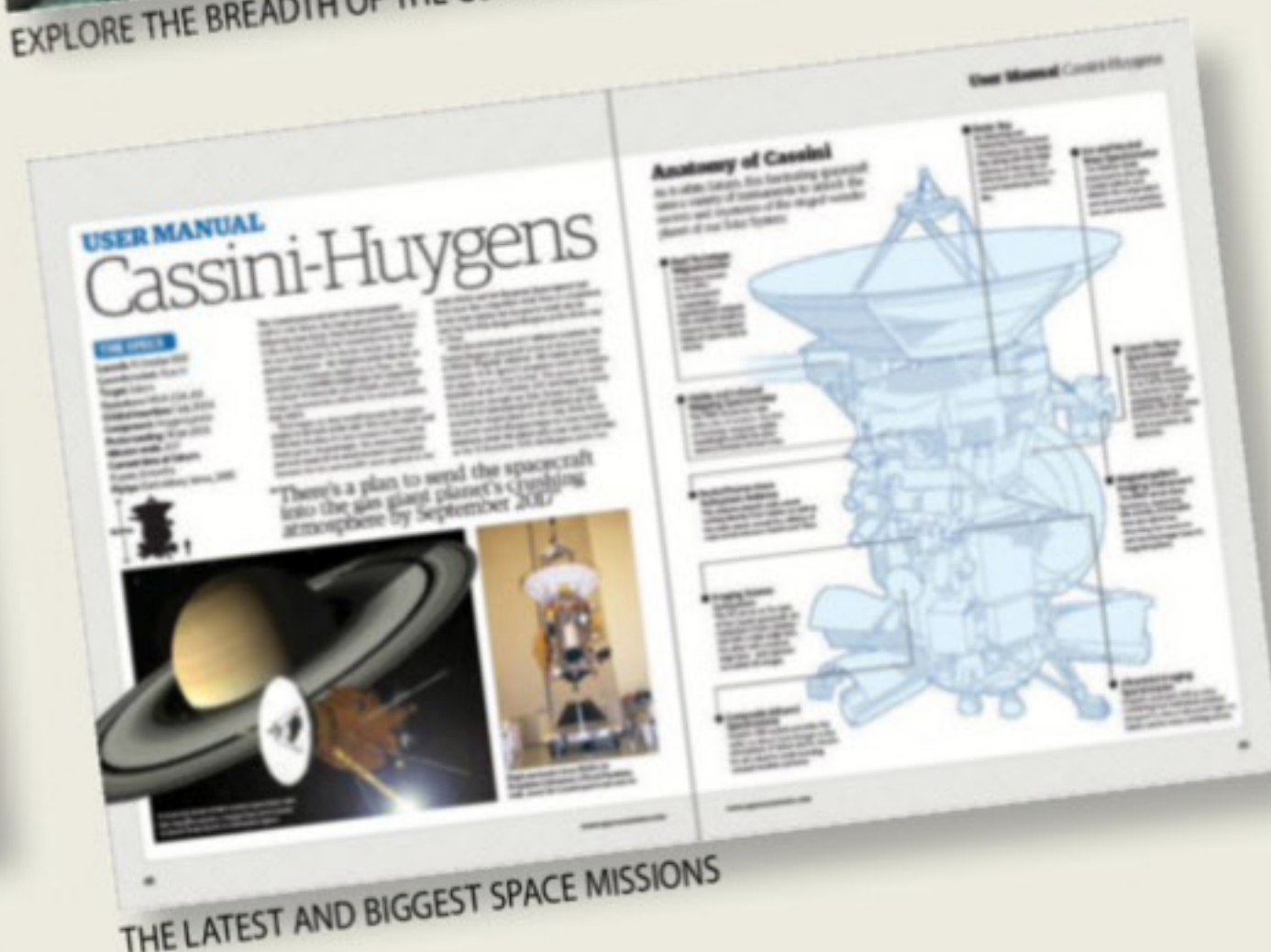
Today there is the Planck satellite, with a much higher resolution map of the universe. The analysis of the Planck data is in remarkable agreement with the simplest models of inflation. All the data suggested that [the fluctuations that made the structures we see today] were sufficient and there seemed to be no need to look for [the first ripples in space-time, or gravitational waves]. Planck only announced a number limit of 11 per cent on [a ratio of gravitational waves to density fluctuations]. Personally I have a bet with Neil Turok, director of the Perimeter Institute, that [this] is at least five per cent. If this is confirmed by future observations, it will be quantum gravity written across the sky. ●

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Venus - when
imaged in ultraviolet
wavebands - takes
on a blue colour

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**National Space Academy
Education Officer**

■ Sophie studied
Astrophysics at
university. She has
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Zoe Baily



National Space Centre

■ Zoe holds a
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Josh Barker



**Education Team
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Gemma Lavender



Senior staff writer

■ Gemma has been
elected as a fellow of
the Royal Astronomical
Society and is a keen
stargazer and telescope
enthusiast on *All About
Space* magazine.

SOLAR SYSTEM

Why does Venus look blue in some spacecraft images?

Harriet Dean

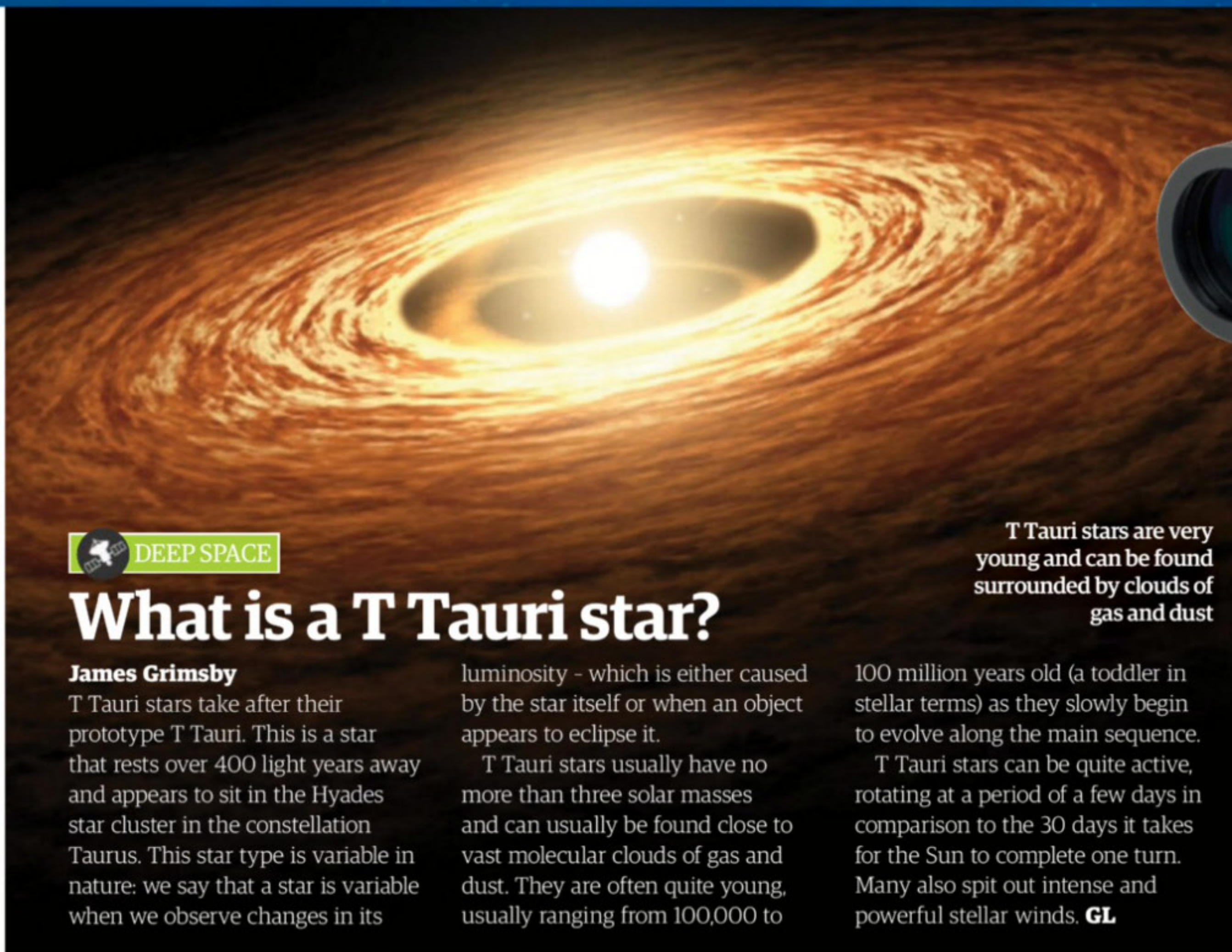
It's all thanks to the filters, which
spacecraft use to image this planet.
Some of the most famous images of
Venus make the second planet from
the Sun appear blue. However, we
know that Venus actually appears

mainly yellow-white to the naked eye.
This blue tinting observed in some
photos is as a result of the filters the
cameras have used to take the image.

Mariner 10, for example, was a 1973
NASA mission to fly by Mercury and
Venus in order to better understand

these worlds. The blue images of Venus
that were beamed back were taken
with an ultraviolet filter making the
planet appear blue, and then these
were further enhanced to bring out the
details of Venus's atmosphere, leading
to an even bluer hue. **SA**

Make contact: @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com



DEEP SPACE

What is a T Tauri star?

James Grimsby

T Tauri stars take after their prototype T Tauri. This is a star that rests over 400 light years away and appears to sit in the Hyades star cluster in the constellation Taurus. This star type is variable in nature: we say that a star is variable when we observe changes in its

luminosity - which is either caused by the star itself or when an object appears to eclipse it.

T Tauri stars usually have no more than three solar masses and can usually be found close to vast molecular clouds of gas and dust. They are often quite young, usually ranging from 100,000 to

T Tauri stars are very young and can be found surrounded by clouds of gas and dust

100 million years old (a toddler in stellar terms) as they slowly begin to evolve along the main sequence.

T Tauri stars can be quite active, rotating at a period of a few days in comparison to the 30 days it takes for the Sun to complete one turn. Many also spit out intense and powerful stellar winds. **GL**

SPACE EXPLORATION

If a nuclear-powered spacecraft exploded in space, would it affect us on Earth?

Keith Watts

Earth wouldn't be affected at all if a spacecraft's reactor managed to explode in space - especially if it's a good distance from our planet.

An explosion like this is likely to cause a burst of X-rays and gamma

rays. If these were to hit the Earth, they would be absorbed by our atmosphere, a protective barrier that also does a good job of absorbing harmful radiation from the Sun.

Of course, nuclear power can be extremely dangerous but is still a

highly considered source to propel spacecraft through to the outer Solar System without the need for large solar panels, which would immediately become impractical the further the mission moved away from the Sun. **GL**



A pair of 20x80 binoculars is considered to be a stepping stone towards purchasing a telescope

ASTRONOMY

Are 20x80 binoculars suitable for beginners?

Jamie Lewis

Binoculars of this size are often used as a stepping stone towards telescopes for beginners. Often it is recommended that you start smaller as larger pairs such as these can be bulky to hold and more expensive than entry sets. Once you get to this size of binocular the need for a tripod can begin to present itself. The larger a pair of binoculars get, the narrower their field of view. This can magnify the effect of shakiness when holding them, so a tripod can help alleviate this. That said, a pair of 20x80s are good for short bursts of handheld viewing. **JB**



NASA's New Horizons spacecraft uses a reactor to propel itself through space

Many asteroids - like 25143 Itokawa - take on weird and wonderful shapes and features



 SOLAR SYSTEM

What asteroids have we found that are particularly strange?

Matthew Clews

Asteroids tend to be fairly irregular and are generally found in the chaotic asteroid belt. There are several asteroids we find that stand out from the masses due to their strangeness. Ceres is the largest asteroid in the belt,

so large that it's spherical and often considered a dwarf planet. To further add to its oddness, it is thought Ceres may have large stores of water ice.

Kleopatra is another bizarre object. Containing large amounts of metal, this bone-shaped asteroid is not alone

on its cosmic journey. Kleopatra is one of many asteroids to have moons, in this case having two, known as Alexhelios and Cleoselene.

Many other odd asteroids exist and there are many more that we don't even know exist yet. **JB**

 ASTRONOMY

Why don't all telescopes have counterbalances?

John Green

The presence of a counterbalance on a telescope is governed by its size. Some telescopes are small enough and arranged in such a way that means they do not require them: effectively, they're intrinsically balanced.

Typically larger telescopes have larger optics systems. These are usually weighty pieces of glass making up the lenses and mirrors. In larger systems these may be off-centre or just too much for the bracket locking systems to hold in a stable position. To help compensate for this counterbalances are required. Counterbalances help to stabilise the telescope to allow for clear viewing. Generally the larger the telescope, the heavier the counterbalance will be. **SA**



Counterbalances are proportional to the size of the telescope: so big and heavy counterbalances are often found on big telescopes

 SPACE EXPLORATION

What was the name of the first spacecraft to arrive at a planet?

Graham Tanner

This depends on what your definition of 'arriving at' a planet is. Planetary exploration has had many failures, and success came in small steps. The first spacecraft to successfully 'graze' another planet was NASA's Mariner 2, during its flyby of Venus in 1962.

The first spacecraft to actually land on another planet was the Soviet Venera 3 craft in 1966, however contact was lost with the craft before landing, so to be more accurate we should say it was the first to crash on another planet.

The first successful landing, with data transmitted back to Earth was in 1970 with Venera 7, again a Venus mission. This mission transmitted 23 minutes of data from the planet's surface. **SA**



NASA's Mariner 2 (pictured) was the first spacecraft to skim Venus but it was the Soviet's Venera 3, which made the first ever landing on the hellish world

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DEEP SPACE

Is dark matter hiding a mirror world?

Rebecca Hunt

Dark matter is a poorly understood material that dominates our universe. As a result of this lack of understanding there is a lot of speculation surrounding it.

One of these ideas is that dark matter could hide a lot of information new to science. Because we think that the majority of the universe is made up of dark matter, it means we still have a lot to understand.

However it may not be that simple, because the very existence of dark matter is still being called into question. The reasoning behind the name 'dark' is that it doesn't interact with most of the universe around us. This makes it incredibly tricky to detect. While we have found and can observe the effects of this material, direct observations are few and far between. **ZB**

Since we don't understand a great deal about dark matter, there is a great deal of speculation that surrounds it

DEEP SPACE

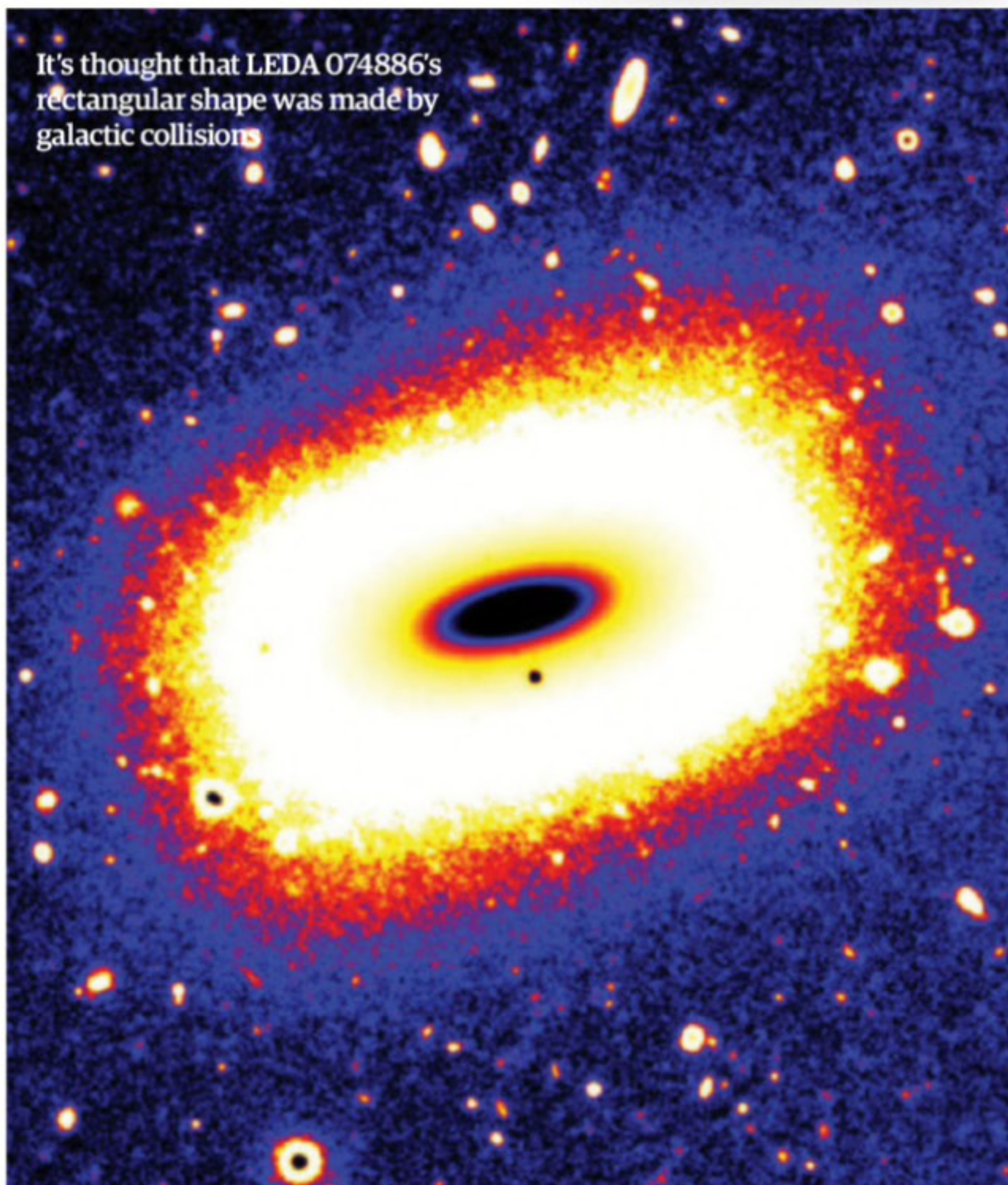
Have astronomers really discovered a rectangular galaxy?

Sam Harwood

Yes, in 2012 astronomers discovered the very unusual rectangular dwarf galaxy LEDA 074886, which rests 70 million light years away and was imaged by the ground-based Japanese Subaru Telescope. It's quite an exciting find since galaxies in general don't usually take on a shape like this. At first, astronomers thought that its weird structure could be explained by gravitational lensing, a phenomenon in space where matter bends light, making objects appear to be magnified. However, it's now suspected that the dwarf galaxy was made by the collision between other galaxies in its local group.

Combined with its odd shape, LEDA 074886's internal stellar disc is aligned in such a way that it appears edge-on to us here on Earth - that means we're unable to check for sure if it has a spiral structure or not. **GL**

It's thought that LEDA 074886's rectangular shape was made by galactic collisions



Quick-fire questions

@spaceanswers

Why are some binoculars filled with nitrogen or argon gas?

Nitrogen gas is often included in the manufacture of binoculars to prevent the lenses from fogging up or filling with water due to condensation.

Who gave Jupiter its name?

Jupiter has had many names throughout history but it was the Roman Empire who had the greatest influence on the planet's name. They named it after the Roman god of sky and thunder.

How do the stars move through our galaxy?

Stars orbit the centre of the galaxy, however, this is not on a perfectly circular path - stars also have random motions where they might suddenly move off at a few tens of kilometres per second.

Do black holes die?

Just like stars, a black hole has a finite life. Black holes emit radiation called Hawking radiation (named after its discoverer, Stephen Hawking) and the more it radiates, the more it shrinks until it evaporates.

Does the Moon rotate?

Yes, the Moon does rotate. However, it does it in such a way that we only see one side of it.

How much time do astronomers spend looking through telescopes?

Professional astronomers spend the majority of their time working on computers, with just a small proportion of their time at telescopes recording data.

How long does the explosive supernova stage of a star last?

A supernova explosion lasts for a very short period of time - usually around 100 seconds.



Quick-fire questions

@spaceanswers

Are there stars outside galaxies?

Yes, there are stars outside galaxies. Astronomers think that when there are collisions or interactions between galaxies, their stars are ripped out.

Does the Sun have any other name?

Our Sun doesn't have another name, however, it is put into a class based on its temperature, size and luminosity. As a result, it is referred to as a G2V star.

Was Stonehenge built for astronomical purposes?

Thoughts on this are mixed. On the day of summer solstice, the Sun appears to rise directly over one of the stones - some think this isn't a coincidence and that it was built to serve as an astronomical calendar.

Why does the SETI project search for radio signals?

Radio signals are able to travel for long distances and through large amounts of dust and the most abundant element in the universe, hydrogen, radiates at this wavelength.

When will Betelgeuse explode?

You might have heard that this red supergiant is likely to go supernova 'soon'. However, this is astronomically speaking - Betelgeuse will explode within a million years.

What is sidereal time?

Sidereal time is measured according to the positions of the stars in the sky. In comparison a sidereal day lasts 23 hours, 56 minutes and 4.1 seconds, while a mean solar day (the day we're used to) lasts 24 hours.



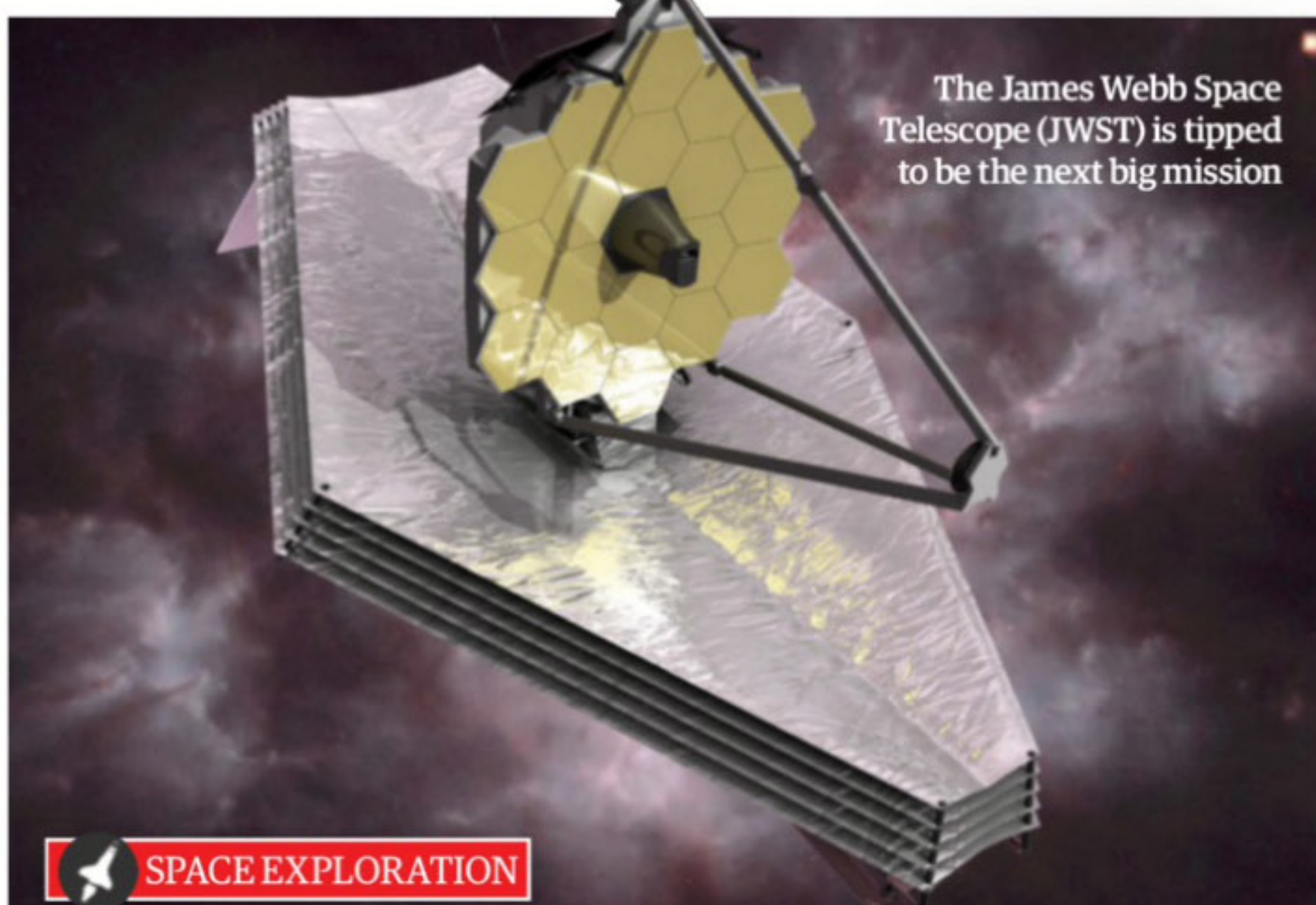
When is the best time to observe Betelgeuse?

Mark Williams

Betelgeuse is in the constellation of Orion, which is best observed during the winter. Being 500 times bigger and throwing out around 16,000 times more visible light than the Sun, this red giant star is easily visible to the naked eye at a magnitude +0.42 - despite being 643 light years away.

If you're in the northern hemisphere, then you will see Betelgeuse rising in the

east just after sunset during the earlier part of January. However, during the months either side of this time period - namely mid-September through to mid-March, Betelgeuse is visible to virtually everyone, all around the globe. While this red giant star can be seen during the summer, the darker nights of winter provide better viewing conditions for those wishing to observe it. **GL**



The James Webb Space Telescope (JWST) is tipped to be the next big mission



What will be the biggest mission in the next decade?

Christopher Lane

The biggest mission in the next decade is probably the James Webb Space Telescope (JWST), which is tipped for launch during 2018. The JWST is often referred to as the successor to the Hubble Space Telescope, however, this next-generation telescope will be slightly different since it will study the universe in the infrared spectrum.

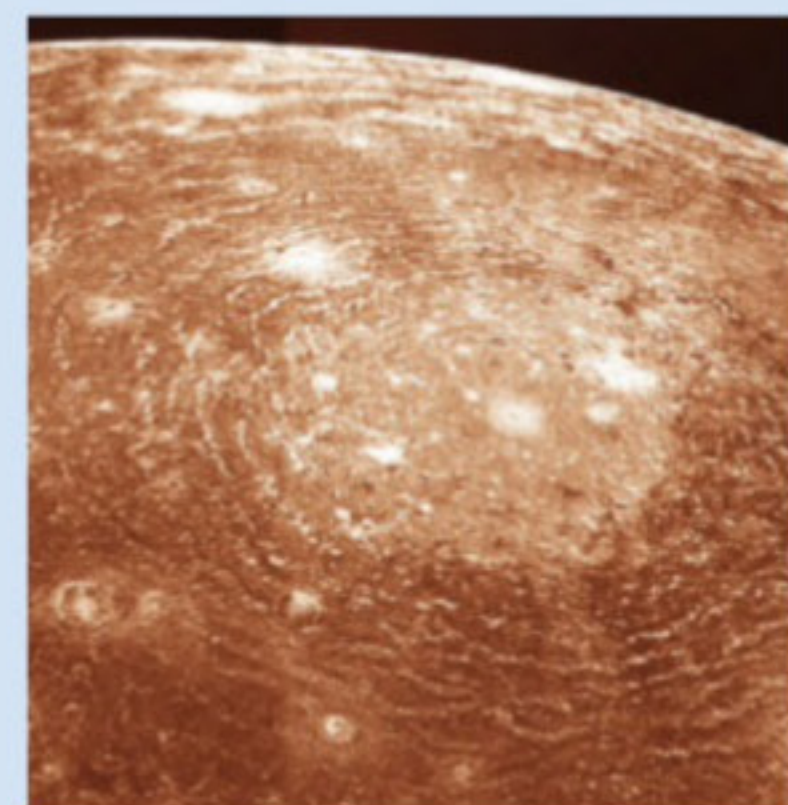
The JWST is quickly becoming one of NASA's most expensive missions

as excessive delays have pushed back the launch date and pushed up the price tag. As a result of this, the new telescope will undoubtedly be one of the costliest missions of the decade, so NASA is pinning its hopes on it being the biggest and best.

Certainly in terms of discovery there is a belief that this mission has the potential to give us a much deeper look and understanding into our universe. **ZB**

The distinctly reddish Betelgeuse is due to go supernova in the next million years

Betelgeuse is best observed during the winter months



Most of the United States could fit into Callisto's giant crater



How big is the largest crater on Callisto?

Jon Gray

An impact basin known as Valhalla is Callisto's largest crater with a diameter of over 300 kilometres (190 miles), while concentric rings that surround it extend out to 3,000 kilometres (1,900 miles) - nearly large enough for the entire USA to fit within its boundaries. Made of rock and ice, this moon of Jupiter is one of the most cratered worlds in the Solar System. In fact, Callisto's surface is so battered that any new impacts on its surface will likely erase older craters.

Just how Callisto got its battered surface is a tale that's also true of other bodies in our Solar System, such as our Moon. It's suggested that Callisto got its distressed surface with the help of a period of heavy bombardment from asteroids and comets, around 4 to 3.8 billion years ago. **GL**

Despite their insatiable appetite, a black hole can never be filled up

DEEP SPACE

Can a black hole ever fill up?

Sarah Creasor

No, in fact they are a result of something being filled too much. Black holes form when a colossal amount of material gets crammed into a tiny space that's much too small for it all to exist at once. When this happens, it collapses into something called a singularity. This infinitely small point contains all the mass and the subsequent gravity

that results from it. Because of the huge amount of mass, close to the black hole the gravity is so strong that nothing can escape. This strong gravity pulls material into the black hole and it will consume until there is nothing left around it. Once it has cleared out the area around it, it may eventually evaporate away in a process taking billions of years. **JB**

Surprisingly you would weigh the least on Mars rather than Mercury (inset)

SOLAR SYSTEM

On which planet would I weigh the least?

John Marks

You might be surprised to know that you would weigh the least on Mars, out of all of the planets in our Solar System. It's quite easy to think that you would weigh the least on Mercury but given that it's denser than the Red Planet, the gravity is stronger here therefore making you weigh more.

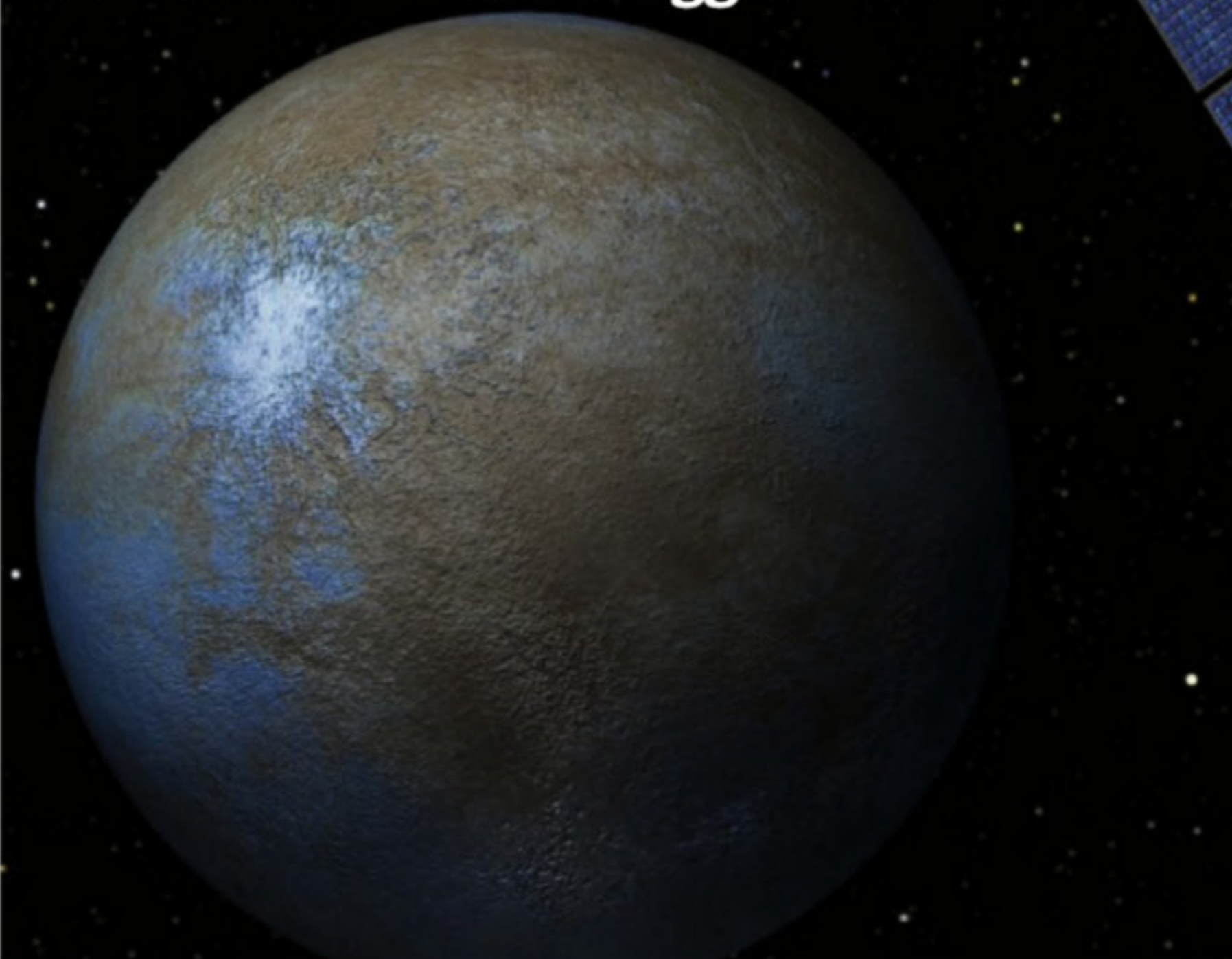
Between Mars and Mercury, the difference in your weight would be quite small. For instance, if you weighed 70 kilograms (154 pounds) on Earth, then you would weigh around 26.39 kilograms (58.2 pounds) on Mars and 26.46 kilograms (58.3 pounds) on Mercury. As the planets get more massive, the more you will weigh. If you could stand on Jupiter, your 70-kilogram (154-pound) weight would nearly triple, to 165.2 kilograms (364.2 pounds). **GL**

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Next Issue

CERES: ASTEROID BELT GIANT

Discover the Dawn probe's mission to the asteroid belt's biggest rock



THE SEARCH FOR NEW EARTH

Brian Cox tells All About Space about life on distant planets

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10 OUT-OF-THIS-WORLD ROVERS

The relentless robotic explorers that have transformed our view of the planets

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HOW TO SPOT AN ASTEROID
OFF-WORLD GREENHOUSES
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WHICH ARE THE BIGGEST TELESCOPES?

In orbit
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STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

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Discover the total solar eclipse

With the astronomical event of the year just around the corner, **All About Space** provides everything you need to know about this rare cosmic event



Safety first!

Remember, that you should never look at the Sun. While it's safer to look at our star during totality, even experts wear eye protection or take other precautions. Observing our Sun can be extremely dangerous if proper precautions are not put in place and, without protection, permanent eye damage is extremely likely.

It's the event that everyone has been waiting for. An astronomical phenomenon that will see the Moon pass between Earth and the Sun, blocking out its light in an event known as a total eclipse.

Friday 20 March is the date that eclipse hunters and astronomers have pencilled into their diaries, with totality, the point where all of the Sun - save for its wispy outermost atmosphere, the corona - is blocked out by our lunar companion for two minutes and 47 seconds. There is extra excitement since these events are quite rare for those in the northern hemisphere, with a good proportion of individuals clamouring for the best spot to witness the day gradually turn into an eerie nightly glow.

Whether you have booked yourself on to a dedicated tour with like-minded eclipse hunters, are heading to an ideal observing spot with your friends and family or you are simply watching the spectacle unfold from home, **All About Space** has the complete guide to making the most of what is shaping up to be the astronomy event of the year. For those in the Faroe Islands and Svalbard, as well as those getting a good slice of the action in the form of a partial eclipse in Iceland, Europe, north Africa and north Asia, we wish you clear skies and hope you enjoy the show - you won't see another total eclipse for quite some time unless you plan to travel the world.



How much of the eclipse can I see?

Northern parts of the world all of the way up to the Arctic Circle are the places to be to catch all - or even a slice - of the Moon's occultation of the Sun

When it comes to observing the eclipse of 2015, location is as important as is a sky that's relatively free of cloud. It's true that the further north you move, the higher your chance of seeing 100 per cent totality. For anyone who is travelling to or is already situated in either the Faroe Islands or Svalbard, you will be treated to an excellent show provided there are no thick clouds to block the view.

While these are ideal locations to be at on 20 March, you don't need to travel too far if you are a resident of Iceland, Europe, north Africa or north Asia. Iceland, northern parts of the United Kingdom as well as Ireland and the Isle of Man are the next best places to be with at least 90 per cent of the Sun's surface covered by the Moon. Observers in Iceland, for example, will see about 98 per cent obscured.

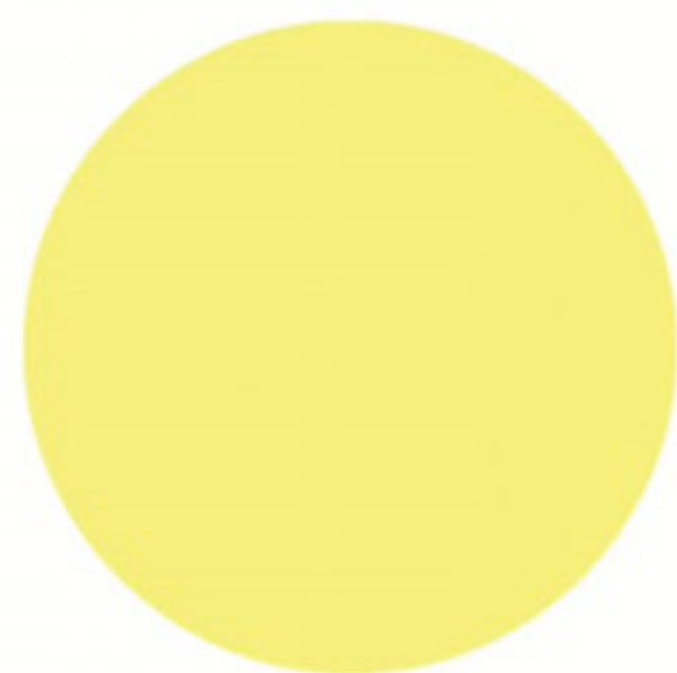
If you're living in the southern part of the United Kingdom, then you will see a partial eclipse of less than 90 per cent solar coverage, while those in Istanbul, Turkey will see up to 40 per cent. But those being treated to anything other than a total eclipse shouldn't be disheartened, a partial occultation can be spectacular to watch in its own right.

Events like these are often over in minutes. That's why it is worth noting that times will be different depending on where you are in the world.

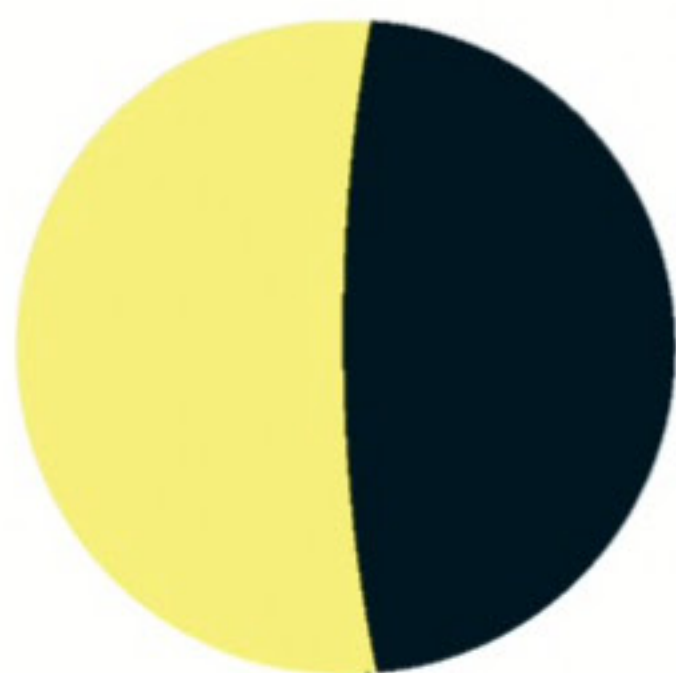
If you are looking to get the best view of the eclipse possible - or even if you're just looking to stay at home - you can use our map to find out how much of the eclipse you can see. Remember, whether you're looking at a total eclipse or a partial the risks of damaging your eyesight are the same - never look at the Sun unless you have the essential equipment to do so.



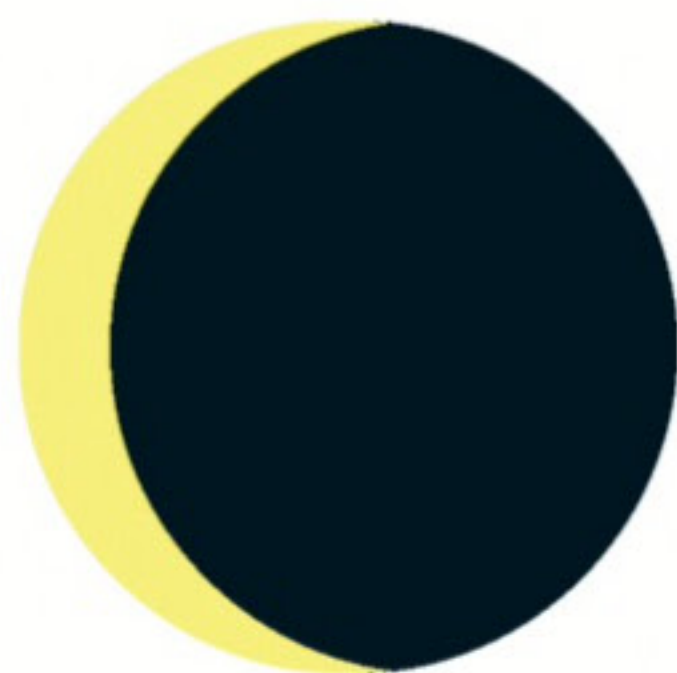
How much of the eclipse can I see?



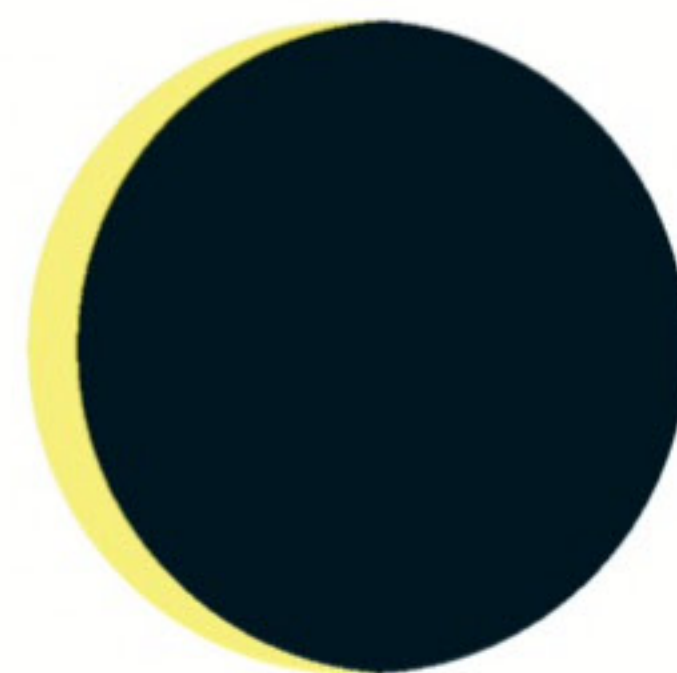
No eclipse



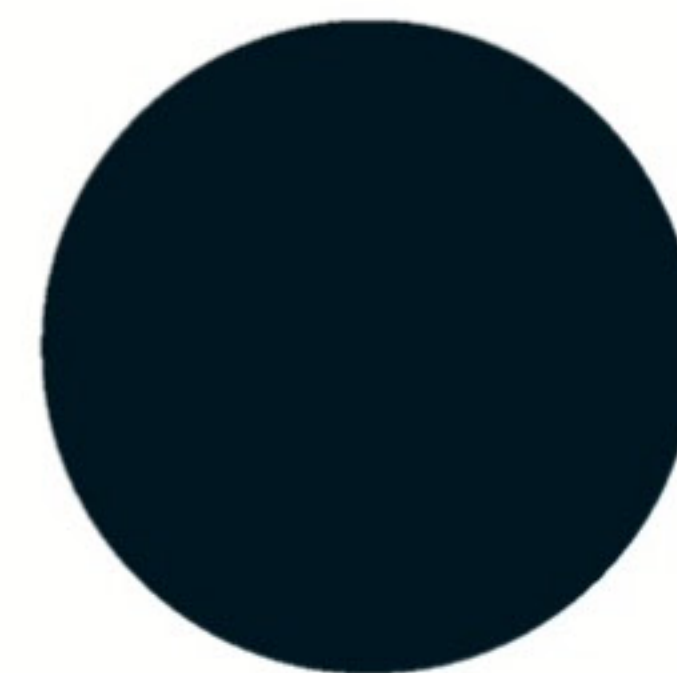
Up to 40%



Up to 90%



Over 90%



Total eclipse



Discover the total solar eclipse

Top 10 places to view the total eclipse

01 Faroe Islands, Denmark **100% totality**

Partial solar eclipse begins: 8:39am Western European Time (WET)

Total solar eclipse starts: 9:41am WET

Maximum eclipse: 9:42am WET

Total solar eclipse ends: 9:43am WET

Partial solar eclipse ends: 10:48am WET

02 Longyearbyen, Svalbard **100% totality**

Partial solar eclipse begins: 10:12am Central European Time (CET)

Total solar eclipse starts: 11:11am CET

Maximum eclipse: 11:12am CET

Total solar eclipse ends: 11:13am CET

Partial solar eclipse ends: 12:12am CET

03 Nuuk, Greenland **Over 90% totality**

Partial solar eclipse begins: Below horizon

Greatest eclipse: 6:31am West Greenland Time (WGT)

Partial solar eclipse ends: 7:27am (WGT)

04 Reykjavik, Iceland **Over 90% totality**

Solar eclipse begins: 8:38am Greenwich Mean Time (GMT)

Greatest eclipse: 9:37am GMT

Partial solar eclipse ends: 10:39am GMT

05 Scotland, UK **Over 90% totality**

Partial solar eclipse begins: 8:30am GMT

Greatest eclipse: 9:35am GMT

Partial solar eclipse ends: 10:44am GMT

06 Dublin, Ireland **Over 90% totality**

Partial solar eclipse begins: 8:24am GMT

Greatest eclipse: 9:29am GMT

Partial solar eclipse ends: 10:37am GMT

07 Oslo, Norway **Over 90% totality**

Partial solar eclipse begins: 9:47am CET

Greatest eclipse: 10:54am CET

Partial solar eclipse ends: 12:02pm CET

08 Stockholm, Sweden **Over 90% totality**

Partial solar eclipse begins: 9:53am CET

Greatest eclipse: 11:00am CET

Partial solar eclipse ends: 12:09am CET

09 Douglas, Isle of Man **Over 90% totality**

Partial solar eclipse begins: 8:27am GMT

Greatest eclipse: 9:31am GMT

Partial solar eclipse ends: 10:40am GMT

10 Rovaniemi, Finland **Over 90% totality**

Partial solar eclipse begins: 11:07am EET

Greatest eclipse: 12:12pm EET

Partial solar eclipse ends: 1:18pm EET



Watching the solar eclipse

How the eclipse works and what you can expect to see on the day

Easily one of nature's most beautiful events, total solar eclipses are a rare sight for many. When a solar eclipse occurs, what you're witnessing is the Earth, Moon and Sun aligning. Eclipses can only really happen at a new Moon. With this in mind, it's quite easy to think that we should get an eclipse every month but because the Moon's orbit around the Earth is tilted by around five degrees to that of our planet's, our natural satellite's shadow usually misses the Earth's surface since it passes above or below the planet at this stage in its lunar phases. It's only really at least twice a year that the geometry lines up just right to make an eclipse for some lucky observers in a particular part of the world.

The Moon's shadow consists of two parts - the penumbra and umbra. It's the fainter, outer penumbral shadow that hits the Earth and enables us to see a partial eclipse at first. It's not until the Moon's dark inner shadow - called the umbra - strikes the planet that we're able to see a total eclipse. The track of the umbral shadow across the Earth is called the Path of Totality. At just 16,000 kilometres (10,000 miles) long and 160 kilometres (100 miles) wide, this is why there are few places in the world where you can see a total eclipse, since this path covers less than one per cent of the planet's surface.

When the Moon passes in front of the Sun, we don't always get a total eclipse. Instead, we get an annular eclipse, also known as a 'ring of fire' - that's when the Moon is at a further distance from the Earth in its orbit and therefore appears smaller, unable to cover the Sun's disc entirely. With the Moon at a distance of around 357,000 kilometres (222,000 miles) from us on 20 March, it will appear large enough in the sky to cover the entirety of the Sun from the more ideal eclipse-watching locations.

Experiencing a solar eclipse is like witnessing no other event. At first, a tiny dent will appear on the eastern side of the Sun's face (western for a southern hemisphere solar eclipse). Initially you won't be able to see it, but that small chunk out of the side of the Sun will become a gigantic bite out of the solar surface. This is point the excitement truly begins.

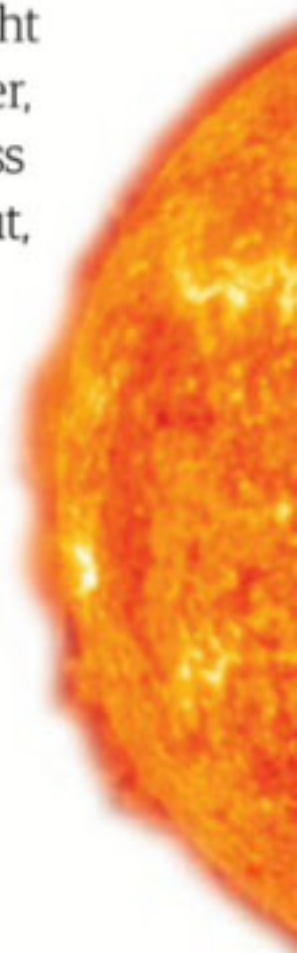
The Moon will leisurely move across the Sun's face for the next half an hour or so. You'll notice that the sky is still quite bright, but then it will start to take on a much deeper blue. The ground around your feet and around you appears dimmer as the ambient light fades to a grey.

When there's about quarter of an hour left until totality, the eastern portion of the sky will be much darker than the west (reversed, for a southern

hemisphere eclipse), no matter where the Sun is. Our star will become an ever-narrowing crescent but will still be incredibly bright, the sky changing to an extremely deep blue, almost purple. It will become darker as the Sun's light gradually becomes extinguished by the Moon creeping across it.

The west will start to darken noticeably and continue to gather strength before spreading out along the western horizon. It won't be long until the minutes to totality turn into the long-awaited seconds and what's left of the Sun is nothing but a bare sliver with Bailey's beads popping into view: these are the final points of bright white light, where sunlight passes through the deepest lunar valleys. A thicker, blacker limb of the Moon continues to move across the Sun's surface until our bright star is blotted out, apart from a white halo. This is what's known as the corona, the Sun's hottest and most extended atmosphere and it shines with a stunning pearly white glow.

At this point we've reached totality and you will now be standing in the shadow of our Moon. A great black disc will replace our Sun. The sky will be so dark that the stars and planets near to the Sun and above our horizon will be visible, almost like night truly has enveloped us.



BBC Stargazing Live 2015

Usually held in January, *Stargazing Live* returns to our screens with Dara Ó Briain and Professor Brian Cox presenting from Jodrell Bank Observatory, which hosts a number of radio telescopes in Cheshire, to coincide with the solar eclipse. The show will begin on 18 March and will run all of the way through to 20 March.



Using a bucket of water

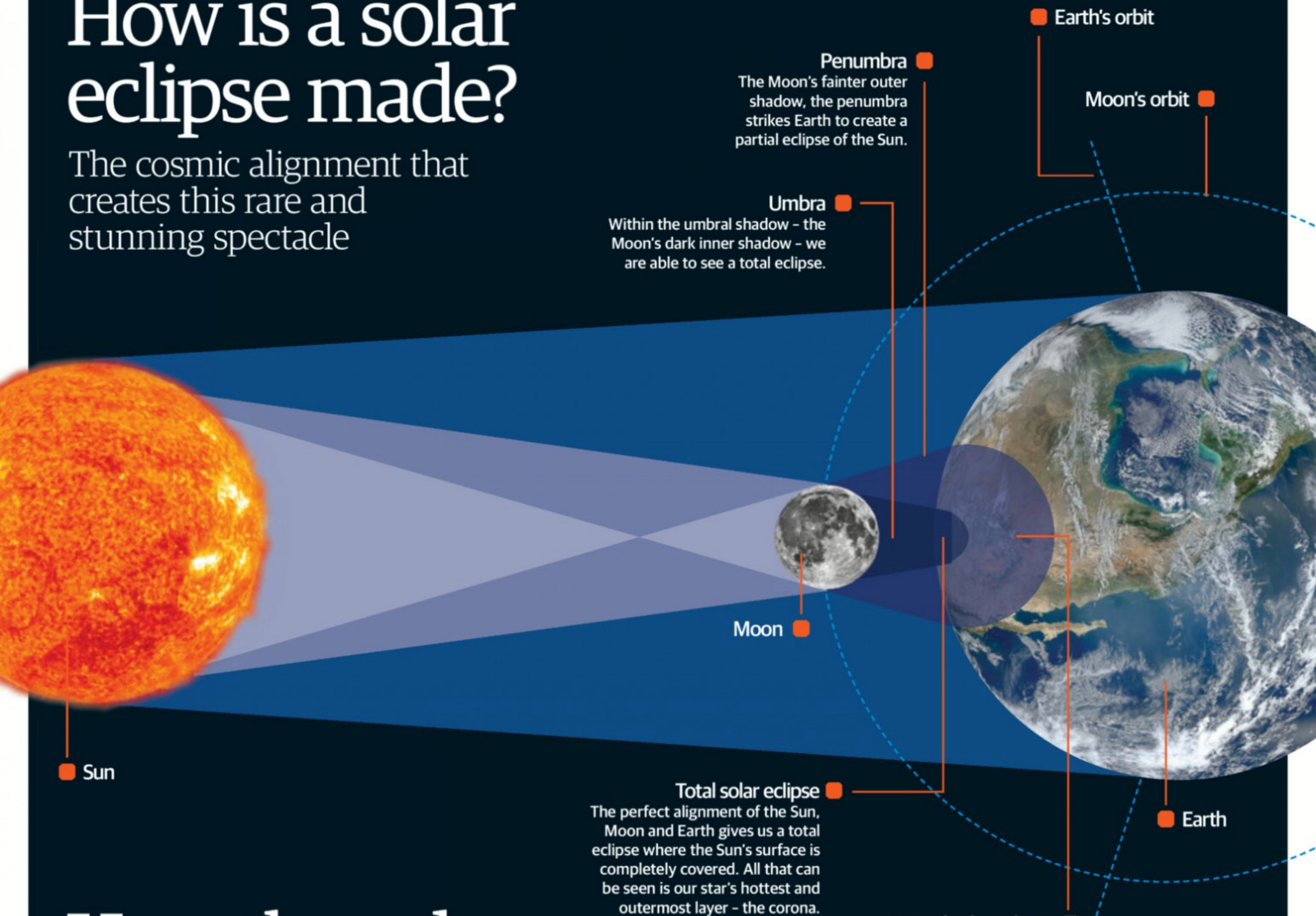
A zero-cost, quick and easy way to observe the solar eclipse is by using a bucket of water to reflect the Sun. In order to make the water appear 'murky' and get the best reflective surface possible, line the bucket with a black bin liner.



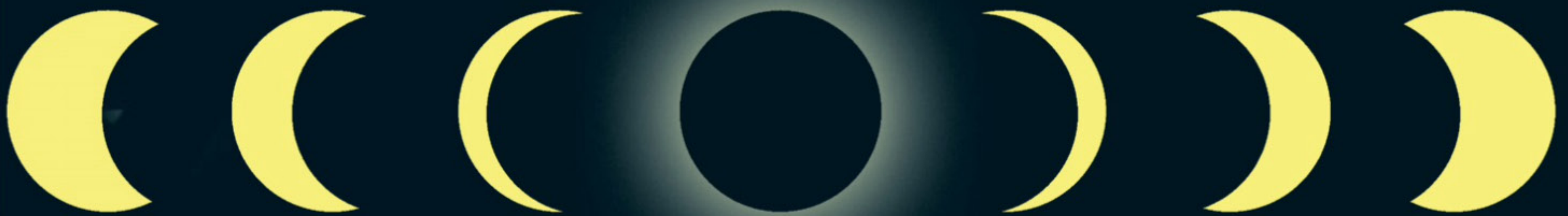


How is a solar eclipse made?

The cosmic alignment that creates this rare and stunning spectacle



How the solar eclipse looks from Earth



Moon moves from the right to left across the Sun (left to right in the southern hemisphere)



What kit do I need?

Whether you're looking to capture the moment or just want to observe, we have the kit that's perfect for watching the eclipse

With the Sun being a dangerous object to look at, many might shy away from solar observing. However, provided you have the right kit and you ensure that you take care when viewing the incredibly bright surface, looking at our nearest star can be a truly breathtaking experience. With the solar eclipse on the way and whether you have a solar telescope or a pair of glasses made especially for the event, all protected eyes will be on the Sun this spring.

Given that it's a great astronomical event, it's easy to rush out to buy a solar telescope. Unless you know a keen solar observer who will allow you to use their instrument, a decent solar telescope will cost a few hundred pounds - an expensive price tag if you don't plan to use it to observe the Sun, along with its stunning solar prominences, filaments and sunspots, after the eclipse. Even if you do come across a relatively cheap solar instrument, you should err on the side of caution and ask yourself if you are purchasing from a reputable dealer. Looking through a poorly manufactured or damaged instrument is a mistake that could cost you your eyesight. Remember also, that unless you're interested in looking closely at the Sun's surface, then you are better off watching the eclipse with a wider field of view - either using the projection method (see page 72) or using a pair of specially made eclipse glasses.

Many will want to capture the eclipse in a photograph and just as you should take care in observing it, care should be taken in imaging this rare event. The good news is that pretty much any type of camera can be used, provided it is protected with a solar filter but you should go for one that has a fairly long focal length, which is recommended to produce an image that's as large as possible.

If you're looking for something that's safe yet cheap to buy, then have a browse of our recommended kit. You'll find that this equipment is of high quality and, very importantly, is incredibly safe to use to ensure an enjoyable and memorable experience as our Moon drifts in front of the Sun.

Imaging and filming the eclipse

It's easy to image or film the solar eclipse, however, you should ensure that a solar filter covers the lens of your camera throughout the event. Always test your equipment before the eclipse. If you're able to, try to set your camera to manual focus and exposure. Additionally, you should also ensure that your eyes are protected - never look directly at the Sun without protection!

Remember!

If you're looking on purchasing kit for the eclipse, you should ensure that you buy it from well-known reputable dealers and manufacturers such as Baader, Coronado, Lunt and Orion. If you're unsure of using anything you have purchased, then you should avoid using it for watching the eclipse.



■ Sun Projector Kit

Cost: £17.99 (approx. \$28)

From: Green Witch

Practical and easy to set up, this instrument projects the Sun onto a viewing screen and allows you to view the solar eclipse safely. The optics consist of an achromatic glass lens as well as two convex mirrors and the projector can be adjusted from 0 to 90 degrees in order to locate the Sun's position in the sky securely and effectively. Ideal for introducing children to the Sun.

■ Lunt Solar Telescope

Cost: £851.00 / \$1,314.61

From: The Astronomy Centre

Portable and easily mounted on a tripod, Lunt Solar Telescopes are versatile when it comes to looking at all manner of activity on the surface of our closest star. Catch the eruption of solar prominences and flares in the Sun's atmosphere, as well as sunspots and granulation, in complete safety and watch as the Moon's limb blocks them from view during the eclipse.





Solomark Baader solar filter

Cost: £23.60 / \$35.99
From: First Light Optics

An adjustable filter that's able to attach to a variety of apertures, the Solomark Baader solar filter allows you to safely observe the Sun without having to worry about risking your eyesight. Made to a high standard, just affix to the optical lens of your telescope to take in the surface details of our star in an eye-pleasing white colour and to get high-quality images with no distortion.



Jargon Buster

Sunspots

Sunspots are regions on the Sun's surface that appear dark. They are cooler than their surrounding areas by around 1,227°C (2,240°F).

Prominences

Prominences can be found above the Sun's visible surface called the photosphere. They often appear as graceful loops that can stay suspended for a number of days.

Solar flares

Solar flares are characterised as sudden flashes of brightness released by the Sun's angry, volatile surface as ejections of solar material.

Hydrogen-alpha

Hydrogen-alpha is a wavelength, which many astronomers view the Sun in order to pick out its prominences and other features or activity. Hydrogen-alpha gives the Sun's surface a red to orange appearance.

Granulation

Granulation is the 'bubbly' or 'grainy' appearance of the Sun's face caused by currents bringing intense heat to the solar surface.

The focal length

The focal length is the optical length of an eyepiece or telescope. Telescopes with long focal lengths provide higher magnification with a given eyepiece. Focal length is almost always quoted in millimetres.

The aperture

The aperture is the diameter of a telescope's objective lens or mirror. The larger the size of a refractor or reflector's aperture, the greater the light-gathering ability of the instrument and the more detail you can see on target objects.

Baader Solar Eclipse observing glasses

Cost: £2.99 (approx. \$4.60)
From: First Light Optics

Made from the highly regarded Baader AstroSolar safety film, you can watch the eclipse in safety while observing it in real colour. Enabling you to take in the entire experience, the Baader foil reduces the intensity of the Sun's light by 99.999 per cent for safe and memorable experience.



Coronado CEMAX eyepieces and Barlow lenses

Cost: £85.00 / \$79.95 each
From: Telescope House

Specially designed for optimising views of the Sun in hydrogen-alpha wavelengths, the CEMAX series of eyepieces and Barlow lenses magnify and are multicoated to provide excellent contrast. At 1.25" these eyepieces fit a wide selection of solar telescopes and provide good eye relief to ensure comfortable viewing. Available focal lengths are 12mm, 18mm and 25mm as well as a 2x Barlow lenses to magnify your experience.





How to adapt your telescope for safe eclipse observation

No need for an expensive solar telescope – here's a simple and safe solution

The safest, cheapest and easiest way to observe a solar eclipse using your telescope is by using the projection method. The projection method means that you don't have to risk your eyesight since the Sun will be projected onto a surface. Remember, looking at the Sun is extremely dangerous – more so through

the added magnification of a telescope – so ensure that you take care when aligning your instrument. To avoid any accidents, you should test out your equipment with the Sun before the eclipse.

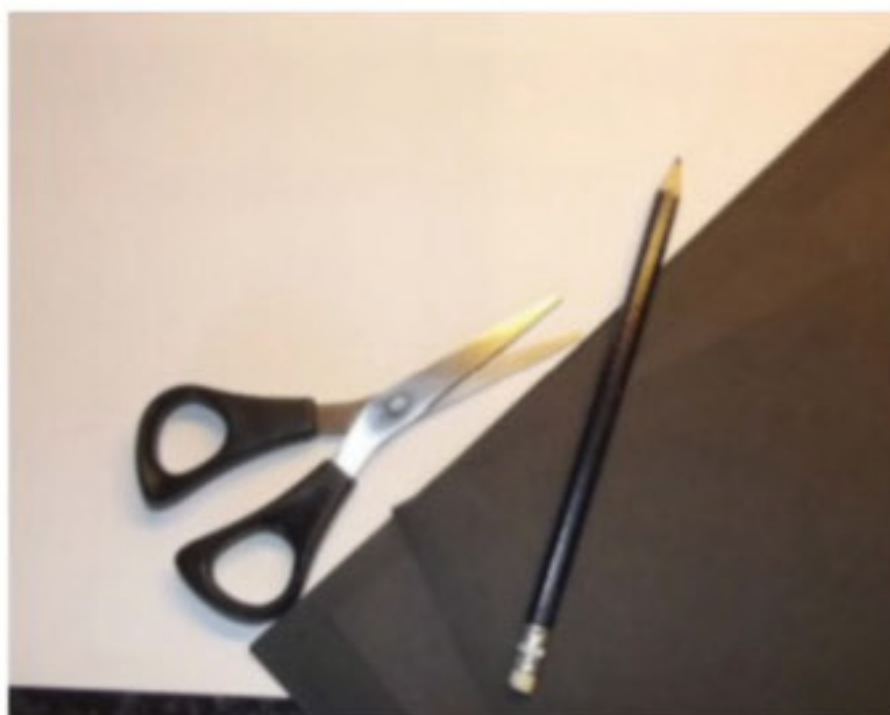
Of course, if you have a solar telescope – or know someone who does – then you can simply point this

specialised instrument at our star. If you would rather buy filters, then ensure that you purchase them from a reputable dealer.

In any case, if you are ever in any doubt whatsoever about the safety of equipment you have purchased, you should always avoid using it.

1 Preparing the card

Grab yourself a large piece of good quality, thick white card or poster board. When selecting this material, the thicker it is, the better, since this is where the Sun's light – and hence the image of the solar eclipse – will be projected. Make sure you have a good, sharp pair of scissors or craft knife for cutting it and something to mark the lines out.



2 Cut around the eyepiece

To ensure optimum safety, you'll need to fit a piece of card around the eyepiece to block out any stray light and that will be used with your telescope. You should remember to remove the star diagonal before you begin and draw around the eyepiece you intend to use. Cut a hole in the card and place it around the eyepiece holder, making sure it fits snugly.



3 Look after your instrument!

Obviously, the Sun is very hot and you should ensure that your telescope doesn't overheat. If you feel that your telescope is extremely warm to the touch, then you should move it out of the sunlight and into a shaded region to cool down. To ensure that danger is kept to a minimum, make sure that your finderscope is capped.



4 Aligning your telescope

Now you're ready to line up your telescope with the Sun. During the process, you might find it tempting to look at the Sun but this should be avoided. While the Sun is large, ensuring that your telescope is pointing at it without the aid of a finderscope can be quite challenging. If you are having trouble, then you should buy a Sun-finder to help you.



5 View your projection

Using the thick white board as a reference, you should focus your telescope until you get a sharp view of the Sun before the eclipse starts. Before the Moon makes its way across the Sun's surface, you should be able to make out sunspots, some solar granulation and limb-darkening on the photosphere – also known as the visible surface of the Sun.

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Take amazing space photos

Start out on the right foot with our guide to astrophotography

There is no denying the beauty of the night sky. The stars, the planets, the Moon, the Milky Way, the northern lights; there is plenty out there to take your breath away. As technology improves and becomes cheaper, using a camera to create your own photographic keepsakes is becoming increasingly popular. It's a particularly compelling hobby when you consider that you are often capturing light that has been on a journey of thousands – and even millions – of years. In many extreme cases, such as far-off galaxies, humans didn't exist when the light captured with your camera first set off.

The equipment, and hence the financial outlay and experience, required to take decent images can vary considerably. The good news is that you can start out with just a camera and a tripod. Or, if you own a telescope and a smartphone, you can buy adapters to attach your phone to the telescope.

Nothing beats practice: astrophotography is all about experimenting with different settings and equipment to see what works best for you. If you want to see how others do it first hand, your local astronomical society can be a great place to learn from those who have been in the astrophotography game for a long time. Don't be intimidated by the wealth of options out there. Taking images of the night sky can get very complicated, but it doesn't have to be. Start out small and work your way up as your confidence and competence increases.

Just like a safari, which has the so called 'big five' animal photography targets, there are five targets in astrophotography which most beginners are keen to shoot: the Moon, a planet, the Milky Way, a constellation and star trails. In this guide we'll give you tips on how to go about ticking these wonders off your astronomical bucket list. Images of lunar craters, the rings of Saturn, the moons of Jupiter and the dust lanes of the Milky Way are all obtainable within a pretty short space of time.

The key to taking good images of the night sky is to get to know both your camera and what you are pointing it at. Make sure you're up to speed on your camera's major settings. Get to know the constellations, the path of the planets throughout the night sky and, perhaps most importantly, the phases of the Moon. Some events are fleeting and so timing can be crucial.

Whatever you decide to do and however you choose to do it, astrophotography can be a very exciting and rewarding hobby. Happy snapping!



Star trails are very popular targets for beginners to astrophotography



You'll need



DSLR camera

You'll need a camera, of course. Some use webcams or CCDs, but a good place to start can be a DSLR because you can attach it to a telescope or take nightscapes of constellations or the Milky Way on a tripod.



Tripod

If you don't attach your camera to a telescope, you'll want to keep your camera stable. Astrophotography can involve taking long-exposure images, so handheld shooting will lead to blurry images.



Telescope

To properly image the Moon, planets and deep sky objects, you'll need a telescope. Refracting (lensed) telescopes are better for planets and reflectors (mirrored) are better for deep space.



T-ring

This is a metal circle that lets you attach your camera to your telescope. Remove your camera lens and screw on the T-ring in its place. The other end will pop into the telescope's eyepiece holder.



Webcam (and laptop)

Sometimes a webcam can be better for imaging than a DSLR as it enables you to record videos, from which you can then take individual frames and stack them using computer software.



Timing and a small amount of luck played a part in taking this beautiful aurora photo

Step-by-step: How to photograph the constellations

1 Focus

The stars are often too dim for your camera to auto-focus (the 'A' setting) on. So the first step is to switch to manual focus mode (the 'M' setting). You'll then need to get the camera focused. The Moon can often be a good object to focus on if it isn't too bright.

2 ISO (sensitivity)

Make sure you know how to change your camera's ISO settings (refer to the camera's manual). The higher the number, the more sensitive the camera is to light. Start with either 400 or 800 to pick up the brightest stars (you can try different settings in subsequent shots).

3 Exposure

The longer you keep the shutter open, the more light you'll collect. Keep it open too long, however, and the stars will start to move due to the rotation of the Earth (star trails). How long you've got depends on your camera, but start with ten-second exposures and then play around.

4 Taking the picture

Now it is time to take your image of the constellation. Look through the viewfinder (or use live view) to frame the stars nicely in the image. Once you're happy, press the button to take the image. Be sure not to knock the tripod during the ten-second exposure time.

5 Stacking (optional)

One way to build up detail and avoid star trails is to take a series of short-exposure images and stack them on top of one another in a computer program such as RegiStax or IRIS. Perhaps try this method once you're comfortable taking images of constellations.

Capturing the sky

Get stunning nightscape images

Astrophotography is not all about the telescope. You can capture wonderful images of the night sky with just a camera and tripod, and there are lots of potential subjects on offer. A lot of people start with the constellations. With dozens to choose from, you could easily spend a lot of time just photographing these famous groups of stars. You'll not only be able to discern the different colours of the stars - like the red of Betelgeuse or the blue of the Pleiades - you should also be able to pick up the fuzziness of nebulae in some constellations. Photograph the area around Andromeda and Cassiopeia, and you might even pick up the distant Andromeda Galaxy (M31).

Newcomers to astrophotography also often like to have a go at images of star trails. As the Earth rotates, the stars appear to move across the night sky in arcs. Long-exposure photographs can capture this apparent motion. Star trail photographs are much more impressive with something terrestrial in the foreground, perhaps a wizened old tree or an expansive, calm lake. Pointing your camera at the Pole Star - which doesn't move as the Earth spins - will provide an image of the nearby stars circling it.

The length of exposure to use depends on how bad the light pollution is in the area you're shooting. In highly polluted areas, for example, you can't go for more than about 30 seconds without the orange hue washing out your image. At truly dark locations, however, it may be possible for you to achieve up to ten minutes of exposure.

While it is possible to image constellations and star trails from light-polluted areas, you're definitely going to need to get somewhere very dark if you want to photograph either the Milky Way or aurorae. The Milky Way appears to us as a dusty rainbow across the sky due to our location inside it. Long-exposure, high-sensitivity photographs are brilliant for picking up the huge swathes of stars, gas and dust that lie between us and the galactic centre (located in the constellation of Sagittarius).

If you want to image aurorae then unless you're very lucky, you'll need to head to a polar region. As charged particles arrive from the Sun, electric currents are generated high in our atmosphere near the poles. When this energy interacts with oxygen, the gas emits beautiful, faint green light.

Winner of Astronomy Photographer of the Year 2014: James Woodend

James Woodend chats about how he got this winning shot

What first attracted you to astrophotography?

I have always been interested in the night sky since I was a small boy. I started taking photographs of the night sky (through telescopes) about 20 years ago - first on film and then later with dedicated digital cameras. It has been only in the last three years or so that I've started to take photographs of the night sky with a consumer-type DSLR camera and wide-angle lenses. I find this area of astrophotography absolutely fascinating and so easy to do. I would encourage anybody with a standard DSLR to have a go at it.

What's the story behind your winning image?

The photograph 'Aurora over a Glacier Lagoon' was taken by me at Jökulsárlón in south Iceland.

I had been to this location several times before and discovered that it would be a good spot for a great aurora photograph. I knew exactly where I needed to be positioned but I need at least five factors to come together.

First, the lagoon itself had not to be totally frozen over (despite being mid-winter), no wind to disturb the lagoon's reflective surface, a clear starlit sky with little or no cloud cover, a faint dash of moonlight (but nothing too strong) to illuminate the glacier and surrounding mountains - and of course an epic aurora borealis. I was fortunate that on 9 January 2014 at 01:42 in the morning all these factors came magically together for me.

What tips would you give anyone looking to take up astrophotography?

My best tip for taking up astrophotography is start simple and work your way up slowly to the more complex stuff. If you are using a consumer DSLR and a wide-angle lens then remember that the camera needs to be on a tripod and that auto-focus does not work at all well at night, so switch the lens to manual and use live view to focus it on a bright star (or the Moon).



Using your camera

Modern DSLR cameras have a myriad of buttons, dials and settings. So it's important to become familiar with your camera before you start trying to take images of the night sky. Knowing how to switch focus from auto to manual, how to alter the aperture and tweak the sensitivity (ISO) are all essential. Another top tip is to get a remote shutter cable. This lets you take the picture without pressing the camera button, which can cause the camera to judder and blur the image, especially with longer exposures.

Nightscapes cheat sheet

Star trails

Exposure: 30 seconds+

Aperture: Try starting with f5.6

Camera sensitivity: 800

Stars appear to move faster the closer they are to the horizon. The closer you are to the area around Polaris and Ursa Major, the higher you can set your exposure. Pick a Moonless night and get as far away from light pollution as possible.

Aurorae

Exposure: 10-30 seconds

Aperture: Widest (smallest number) you can get

Camera sensitivity: ~800

Use a shutter release cable to avoid blurring as you push the button. Equally you could set a two or three-second delay on the camera to achieve a similar result. Check local aurorae forecasts to see when the best time to shoot is likely to be.

Milky Way

Exposure: 30 seconds

Aperture: Smallest f number you can set to

Camera sensitivity: 6400 (or highest you can go)

The densest part of the Milky Way can be seen when looking towards its central bulge (found in the constellation of Sagittarius). Look out for the stars that make up the 'teapot' asterism in particular, as they make a good feature in Milky Way photos.

Landscapes at twilight

Exposure: 15-20 seconds

Aperture: Wide as possible

Camera sensitivity: Highest you can go

Learn the different stages of twilight: civil, nautical and, finally, astronomical twilight. The Sun gets lower below the horizon with each phase, so the sky gets darker. You'll need to play around with optimum aperture settings to get the best results.



Shooting the Solar System

With the right kit, you can capture the planets and the Moon in detail

The Solar System is such a rich reservoir of beautiful things to look at. Venus has its phases, Mars its ice-capped poles and dark brooding surface features. The giant planets have much to offer, too: Jupiter has its famous Great Red Spot and its neighbour, Saturn, boasts a glorious system of rings that, once seen, are never forgotten.

Then there is the Moon, often overlooked but arguably the best thing to look at in the night sky due to its sheer proximity to Earth. As the Moon orbits us, sunlight hits the lunar surface at different angles, illuminating areas that were unseen the night before, or casting the previous evening's centrepiece into dramatic shadow.

The Moon has many jewels to look at and try to photograph, making it an excellent place to start for the budding astrophotographer. You could capture an image of the whole Moon at once, showing off our nearest satellite's array of dark, blotchy 'seas.' You can do that with just a camera, tripod and a high-zoom lens. Or you could attach a camera to a telescope for a chance to snap finer detail such as craters. The best way to navigate the lunar surface is to identify a particularly famous crater - such as Tycho or Copernicus - and use a Moon map to 'crater hop' from one location to the next. Small aperture and low sensitivity (ISO) are the way to go, but you'll need to play around to see what works best.

Unlike the Moon, which is only out of our sky for a few days a month, the planets come and go as they orbit around the Sun. Sometimes they appear close to the Sun in our sky and so, like the Sun, have set by the time darkness falls. Having said that, when the planets do grace us with their presence, they are often very easy to find. They move through the 12 constellations that form the signs of the zodiac, approximately following a line known as the 'ecliptic'. Getting to know these constellations will be valuable for budding astrophotographers. As the Moon passes close to this line too, sometimes you get conjunctions - when a planet is found nestled close to the Moon. Such alignments are an excellent opportunity for a photograph.

Imaging the Solar System is all about experimentation. It is important to play around and see what gives the best results for the equipment that you are using. It's all part of the fun.

A celestial conjunction between Venus, Jupiter and the Moon over the Very Large Telescope (VLT) in Paranal, Chile



Why can't I use my DSLR?

For Solar System targets, particularly the planets, DSLR cameras might work fine. However, you will be taking just one image at a time. It's possible that turbulence in Earth's atmosphere will prove particularly bad at the split second you snap the picture, leading to a blurry image. Atmospheric turbulence is random, so the best way to get around it is to take lots of images and pick the best ones. Rather than shooting with a DSLR, if you use a CCD or a webcam to record video, you can take the best stills from that video instead.

How to image...

The Moon

It is important to image the Moon at the right time. You might assume that photographing it when it is full is best because you can see more of it. In fact, it is best to shoot the Moon when you can see a clear dividing line between the light part and dark part (called the 'terminator'). The shadows created in this region will pick out glorious detail in craters, mountains and volcanic ridges.

Filters, particularly red ones, can also be useful because they often lead to a sharper image. Short exposures (around 1/250th second) avoid overexposed white blobs.



Jupiter

Most decent telescopes will give you a great view of Jupiter's stormy atmosphere. If you want to capture its famous Great Red Spot, then look up online whether it will be visible when you want to observe - it is often carried to the other side of the planet by Jupiter's rapid, sub-ten-hour rotation.

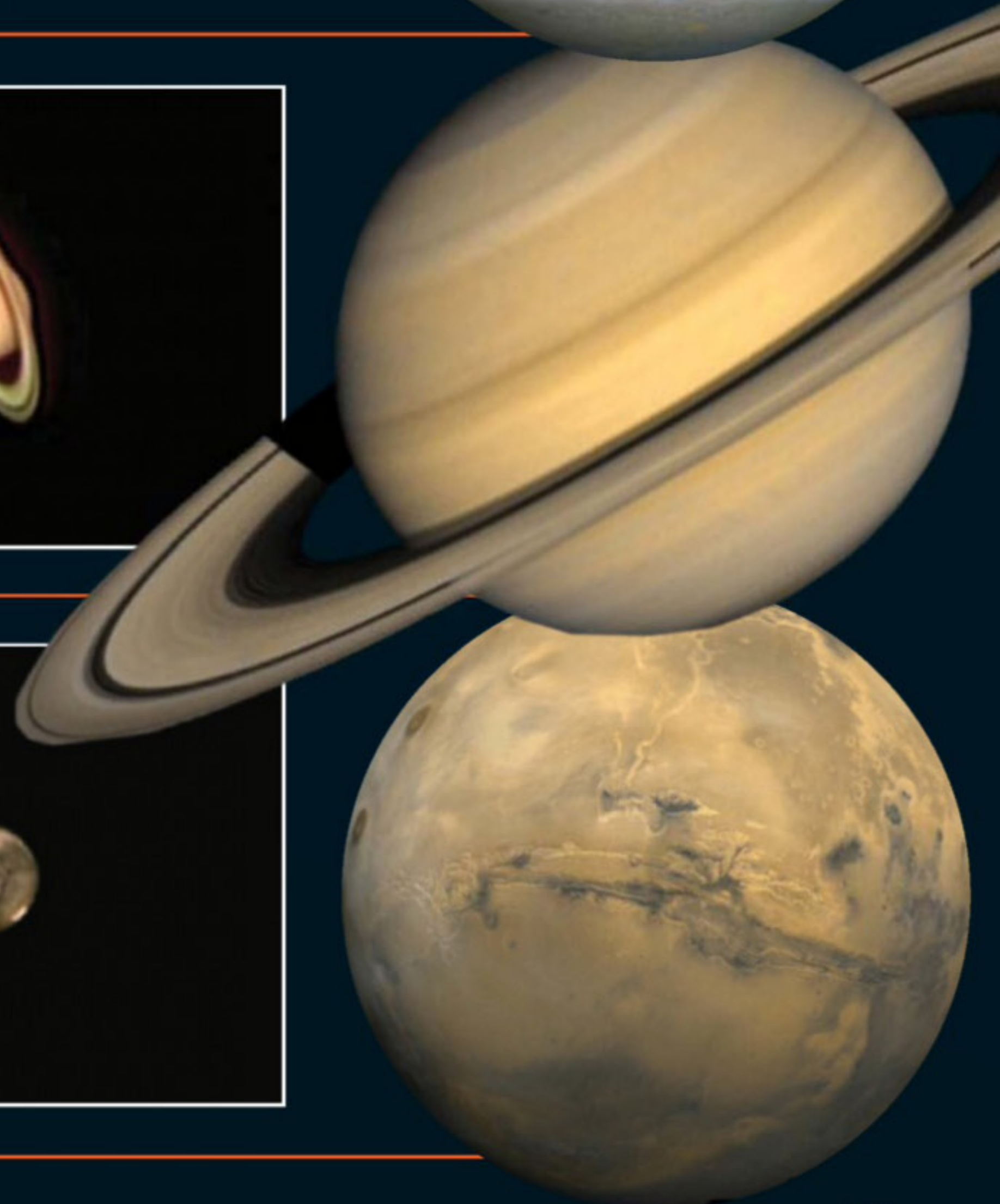
A webcam is often preferred to a DSLR for planetary observing due to the ability to isolate individual frames from a video ready for stacking. Limit yourself to a maximum of two minutes a video, however, as Jupiter's quick spin will start to blur your images.



Saturn

If you're using a DSLR camera to shoot Saturn, you'll need a slightly longer exposure time than for Jupiter due to Saturn being dimmer as it is further from the Sun. Something around the 1/5th-second mark should do the trick.

You should be able to pick up some of Saturn's moons too, particularly Titan, but you'll need a longer exposure (more like 1.5 seconds). Unfortunately this will make Saturn very bright in the image. If you want Saturn and Titan together, take two separate images and combine them later using some imaging software.



Mars

Mars can be tricky. It is a smaller planet than Jupiter or Saturn, and so, despite being closer to the Sun, it appears quite small in even a medium-sized telescope. That closer proximity to the Sun also means it is pretty bright too - its glare can be an obstacle to decent images. To combat this, use red and orange filters to tease out Mars's dark markings.

While it is possible to take images using your DSLR, many astrophotographers agree that when it comes to the Red Planet, a webcam (and stacking) is the way to go. Three to four-minute videos will suffice.





Run the Messier Marathon

This March, there are galaxies, nebulae and star clusters galore – see how many you can spot in **All About Space's** Messier Marathon

Now is one of the best times of the year to be looking up at the night sky. In the weeks around the spring equinox (March 20) the nights remain relatively long and the winter constellations are still hanging around. But the summer constellations are also starting to make an appearance too. For many amateur astronomers this is the 'Messier Marathon' season – a chance to catch many of the stunning nebulae, clusters and galaxies that the Messier catalogue has to offer and all in one evening.

This famous set of objects is named after 18th century French comet hunter Charles Messier. He compiled a list of fuzzy night-sky objects that those looking for comets might readily confuse with the real thing. With a few posthumous additions, his impressive list now boasts 110 entries including some of the most famous objects in the sky, such as the Orion Nebula, the Pleiades cluster and the Andromeda Galaxy. While possible, trying to hunt down all 110 in one evening is quite a task. So in this guide we've put together 30 of the most accessible and beautiful Messier targets that you can find from dusk until dawn.

As these objects are quite faint you are going to need binoculars in all but a few extreme cases. There are some targets – often distant galaxies – that will also require a small telescope. Reflectors (mirrored) telescopes are often the best choice here because you can collect more light for a cheaper price. It is also best to avoid nights when a bright Moon is present. The weekend of 20, 21 and 22 March would be ideal.

If you've not tried your hand at finding globular clusters, galaxies and giant cosmic gas clouds before, there has never been a better time to start. Enjoy your Messier Marathon!



1 M39

Open cluster

Right ascension: 21h 31m 42s

Declination: +48° 25'

Minimum optical aid:
Binoculars

We start our journey low down in the north as soon as it gets dark. The constellation of Cygnus (the Swan) – part of the Summer Triangle – is just skirting the horizon. If you can see the brightest star in Cygnus – Deneb – trace a diagonal line up to the left with your binoculars and you should find this cluster. There are other clusters in quite close proximity which aren't part of the Messier catalogue. You are looking for the brightest of the group.

2 Andromeda Galaxy (M31)

Galaxy

Right ascension: 00h 42m 44.3s

Declination: +41° 16' 9"

Minimum optical aid:
Unaided eye

We are moving slightly to the west and higher in the sky than M39. There are two main ways of finding this famous object which sits around 2.5 million light years from us, making it our nearest major galaxy. The first is to find the 'W'-shaped constellation of Cassiopeia. The three stars on the right of the 'W' form an arrow, which if followed will roughly guide you to Andromeda. Alternatively, find the bright star Mirach and the two stars to the right. Andromeda sits slightly to the right of the top of that line of three stars.





3 Triangulum Galaxy (M33)

Galaxy

Right ascension: 01h 33m 50.02s

Declination: +30° 39' 36.7"

Minimum optical aid: Binoculars

Now move back down that line of three stars returning to Mirach. Then continue that line towards another three stars which make up the constellation of Triangulum (the Triangle). Before you get to those stars you should come across the fuzzy patch that is the Triangulum Galaxy. As a good way of double checking, the galaxy sits slightly to the right of the centre point of the line between Mirach and Hamal (in Aries).

4 M34

Open cluster

Right ascension: 02h 42.1m

Declination: +42° 46'

Minimum optical aid: Binoculars

From M33, head higher in the sky (about 12 degrees) and slightly to the right. Here you'll encounter Almaak - a star that forms part of Andromeda's feet. Now turn your gaze up and to the left towards Algol in Perseus. In between these two stars you will find the open cluster M34. The stars here are thought to be relatively young - only 250 million years old. But even younger stars are up next.



Taurus (the Bull)



05 Pleiades (M45)

Open cluster

Right ascension: 3h 47m 24s

Declination: +24° 7'

Minimum optical aid: Unaided eye

06 Crab Nebula (M1)

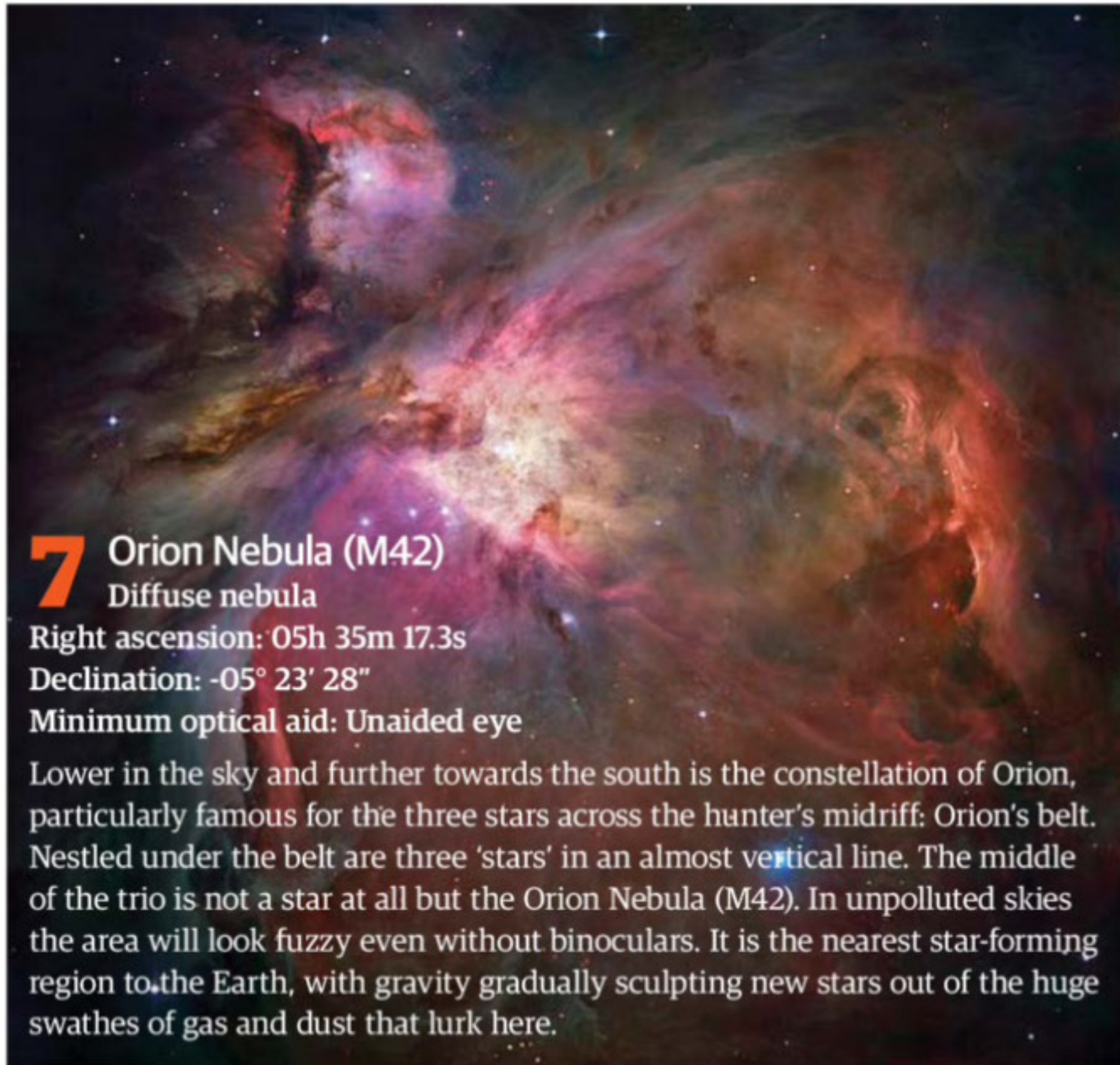
Supernova remnant

Right ascension: 05h 34m 31.94s

Declination: +22° 00' 52.2"

Minimum optical aid: Small telescope





7 Orion Nebula (M42)

Diffuse nebula

Right ascension: 05h 35m 17.3s

Declination: -05° 23' 28"

Minimum optical aid: Unaided eye

Lower in the sky and further towards the south is the constellation of Orion, particularly famous for the three stars across the hunter's midriff: Orion's belt. Nestled under the belt are three 'stars' in an almost vertical line. The middle of the trio is not a star at all but the Orion Nebula (M42). In unpolluted skies the area will look fuzzy even without binoculars. It is the nearest star-forming region to the Earth, with gravity gradually sculpting new stars out of the huge swathes of gas and dust that lurk here.



8 M50

Open cluster

Right ascension: 07h 03.2m

Declination: -08° 20'

Minimum optical aid: Binoculars

Follow Orion's belt down to the left and you'll come across Sirius - the brightest star in the night sky. Kick up and to the left and the next bright star you'll encounter will be Procyon in the constellation of Canis Minor. M50 (the heart-shaped cluster) lies approximately a third of the way along the line between Sirius and Procyon. Omega Canis Majoris also sits almost exactly halfway between M50 and Sirius, which can be a useful way to double check as other clusters do also lie nearby.



9 Beehive Cluster (M44)

Open cluster

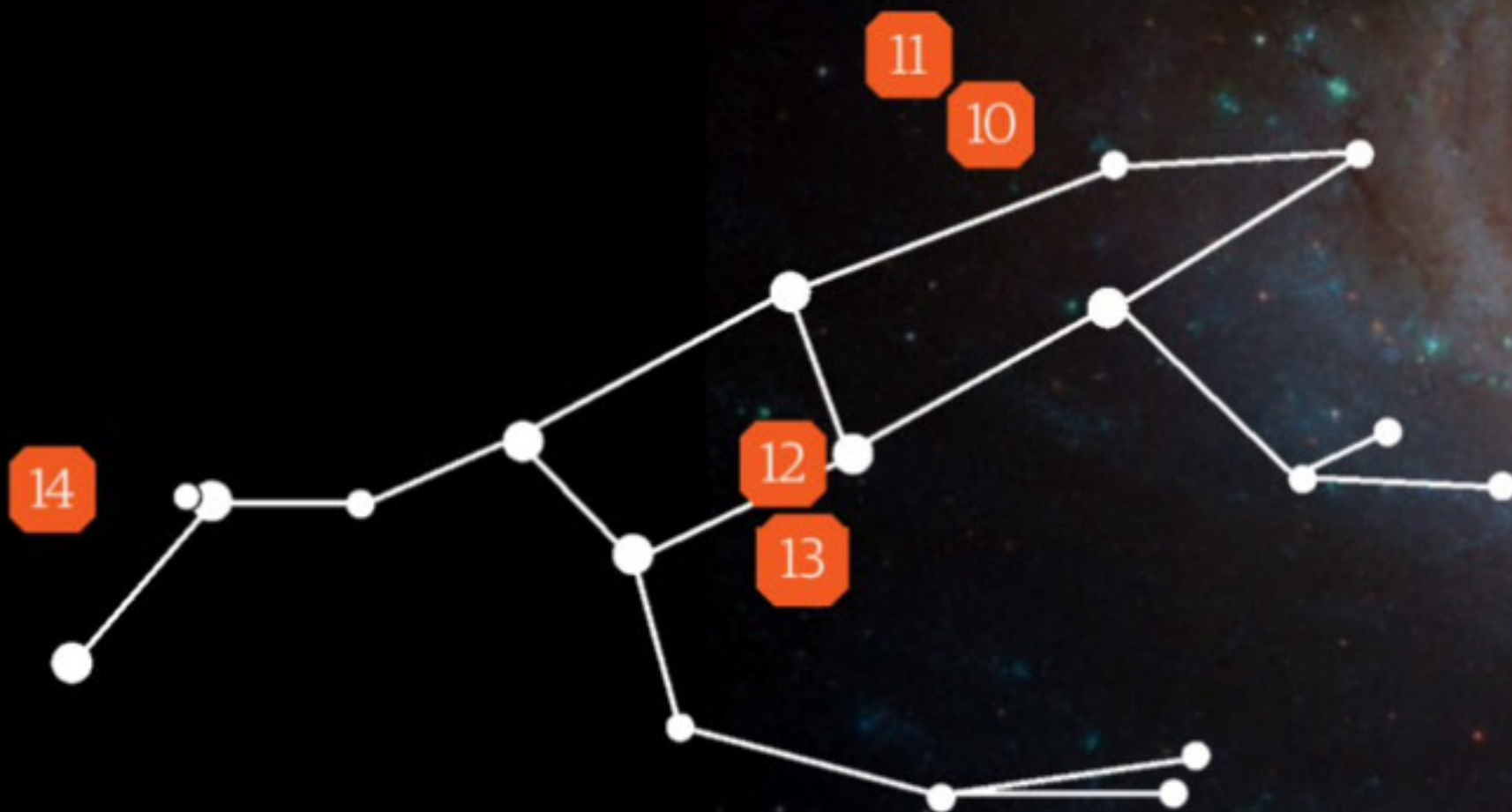
Right ascension: 08h 40.4m

Declination: 19° 59'

Minimum optical aid: Unaided eye

Above Procyon sit the two bright stars Castor and Pollux - the heads of Gemini (the Twins). Join those two stars and follow the resulting line downwards and to the left. If looking in March you will find Jupiter lurking here. M44, often referred to as Praesepe, is just up and to the right of the biggest planet in the Solar System. It is the highlight of the otherwise extremely uninteresting constellation of Cancer (the Crab). Not only is this one of the closest open clusters to us, it also contains more stars than most clusters.

Ursa Major (the Great Bear)



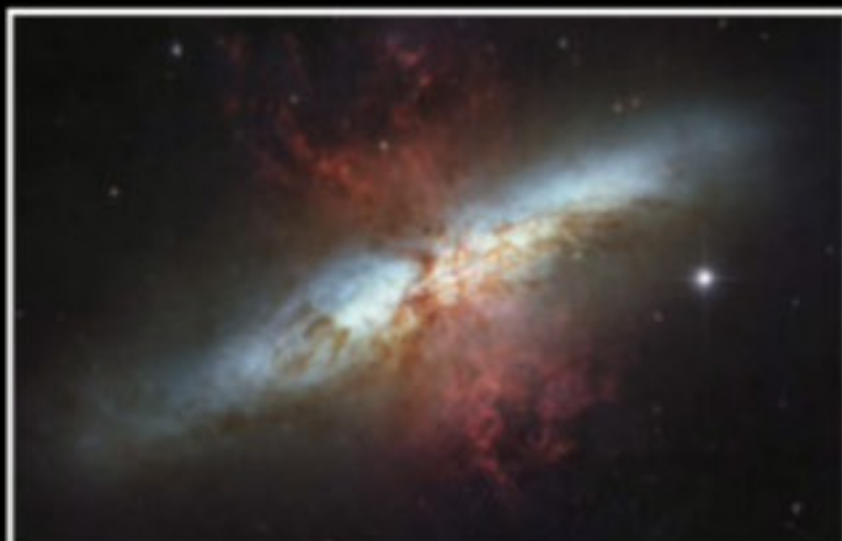
10 Bode's Galaxy (M81)

Galaxy

Right ascension: 09h 55m 33.2s

Declination: +69° 3' 55"

Minimum optical aid: Binoculars



11 Cigar Galaxy (M82)

Galaxy

Right ascension: 09h 55m 52.2s

Declination: +69° 40' 47"

Minimum optical aid: Binoculars



12 M108

Galaxy

Right ascension: 11h 11m 31.0s

Declination: +55° 40' 27"

Minimum optical aid: Small telescope



13 Owl Nebula (M97)

Planetary nebula

Right ascension: 11h 14m 47.734s

Declination: +55° 01' 08.50"

Minimum optical aid: Larger binoculars (say 20x80)



14 Pinwheel Galaxy (M101)

Galaxy

Right ascension: 14h 03m 12.6s

Declination: +54° 20' 57"

Minimum optical aid: Binoculars



15 Whirlpool Galaxy (M51)

Galaxy

Right ascension: 13h 29m 52.7s

Declination: +47° 11' 43"

Minimum optical aid: Binoculars

Skip back across Alkaid (the tail's end star) and you'll find one of the most beautiful galaxies in the sky. In truth, it is actually two galaxies interacting with each other (M51 and NGC 5195). The existence of the companion has been known about since the middle of the 19th century when the Earl of Rosse drew what he saw through his giant 72-inch telescope in Ireland.



16 M3

Globular cluster

Right ascension:

13h 42m 11.62s

Declination: +28° 22' 38.2"

Minimum optical aid:

Binoculars

Continuing to move away from Alkaid and Ursa Major, you will come across Cor Corali and Chara - the two stars that make up the heads of Canes Venatici (the Hunting Dogs). Join the line between them and follow it down towards the horizon. You can't miss the bright red star of Arcturus twinkling away in the constellation of Boötes (the Herdsman). One of the finest globular clusters in the northern sky - M3 - sits just over halfway between Cor Corali and Arcturus. Its 500,000 constituent stars make it one of the brightest global clusters.



17 M53

Globular cluster

Right ascension:

13h 12m 55.25s

Declination: +18° 10' 05.4"

Minimum optical aid:

Binoculars

Go back to Arcturus. Now look up to the right a little and find the star Muphrid. Extend the line between them up and to the right until you encounter the star Diadem in Coma Berenices. Globular cluster M53 lies just one degree away. At 60,000 light years from the galactic centre it is one of the most distant globular clusters.

Virgo (the Virgin)



18 M58

Galaxy

Right ascension: 12h 37m 43.5s

Declination: +11° 49' 05"

Minimum optical aid: Small telescope



19 M86

Galaxy

Right ascension: 12h 26m 11.7s

Declination: +12° 56' 46"

Minimum optical aid: Binoculars



20 M84

Galaxy

Right ascension: 12h 25m 03.7s

Declination: +12° 53' 13"

Minimum optical aid: Binoculars/small telescope



21 M59

Galaxy

Right ascension: 12h 42m 02.3s

Declination: +11° 38' 49"

Minimum optical aid: Small telescope



22 M60

Galaxy

Right ascension: 12h 43m 39.6s

Declination: +11° 33' 09"

Minimum optical aid: Binoculars/small telescope



23 M61

Galaxy

Right ascension: 12h 21m 54.9s

Declination: +04° 28' 25"

Minimum optical aid: Small telescope



24 Sombrero Galaxy (M104)

Galaxy

Right ascension: 12h 39m 59.4s

Declination: -11° 37' 23"

Minimum optical aid: Binoculars



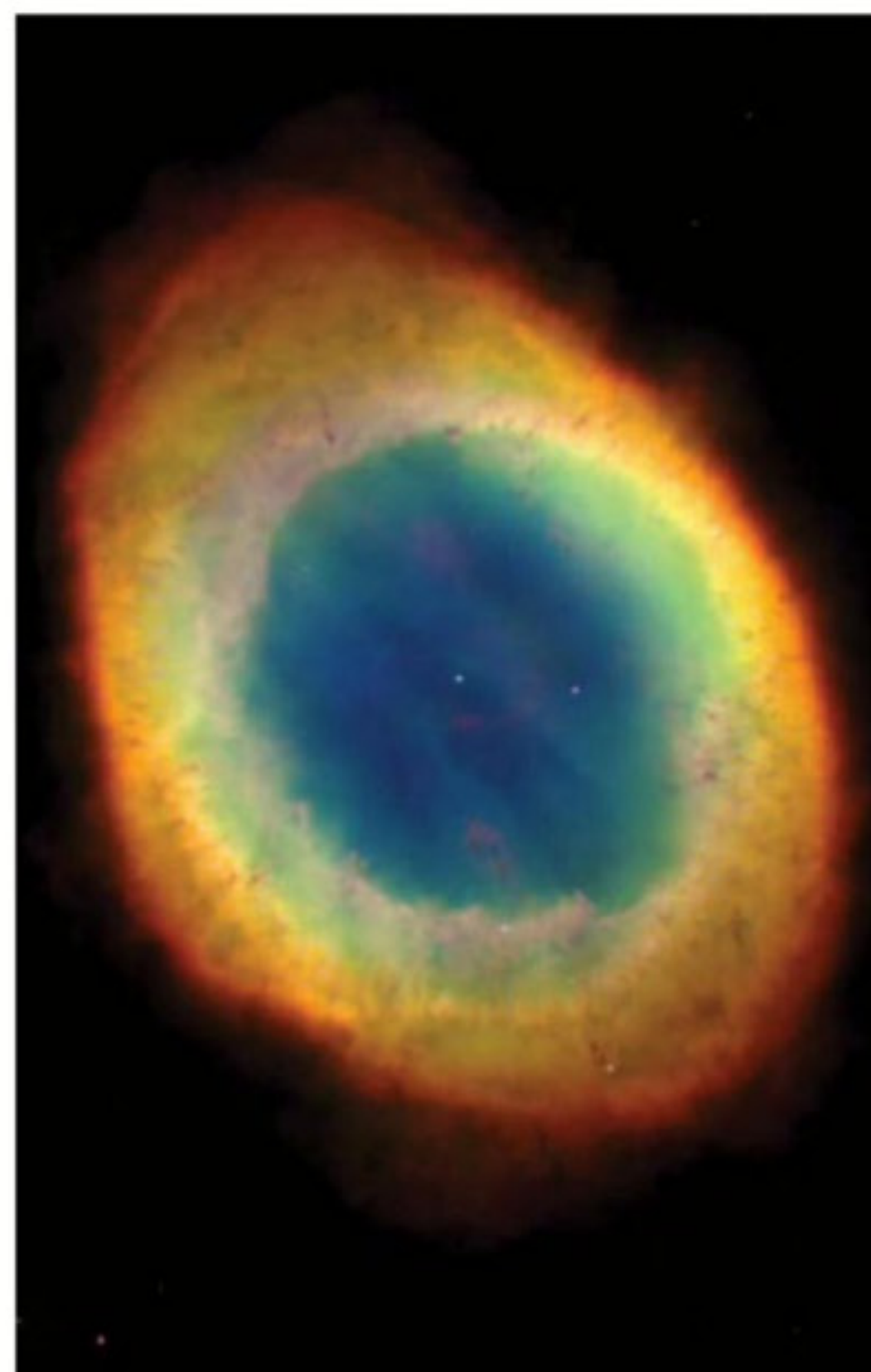
25 Southern Pinwheel Galaxy (M83) Galaxy

Right ascension: 13h 37m 00.9s

Declination: -29° 51' 57"

Minimum optical aid: Binoculars

Towards the end of March, at about 01:00, a galaxy which is traditionally associated with the southern hemisphere pokes its head approximately eight degrees above the horizon. The Southern Pinwheel Galaxy is located on a line that starts with the star Alchiba in Corvus and passes through M68. It sits less than a degree away from the 5.8 magnitude star HIP 66563. No fewer than six supernovae have been recorded exploding in this star city.



26 Ring Nebula (M57)

Planetary nebula

Right ascension:

18h 53m 35.079s

Declination: +33° 01' 45.03"

Minimum optical aid:

Binoculars

The Ring Nebula is a warning - a sign of the fate that awaits the Sun. To see it for yourself, head down and left from M13 in the constellation of Hercules until you reach the stupendously bright star Vega (in Lyra). Then head down towards the horizon and you'll find the star Sulafat. The star Sheliak lies diagonally up to the right. Approximately halfway between them you'll find the Ring Nebula - a star that has shed its outer layers at the end of its life. Our Sun will do the same in around 5,000 million years.

Sagittarius



27 Trifid Nebula (M20)

Emission nebula

Right ascension: 18h 02m 23s

Declination: -23° 01' 48"

Minimum optical aid: Binoculars



28 Lagoon Nebula (M8)

Emission nebula

Right ascension: 18h 03m 37s

Declination: -24° 23' 12"

Minimum optical aid: Binoculars



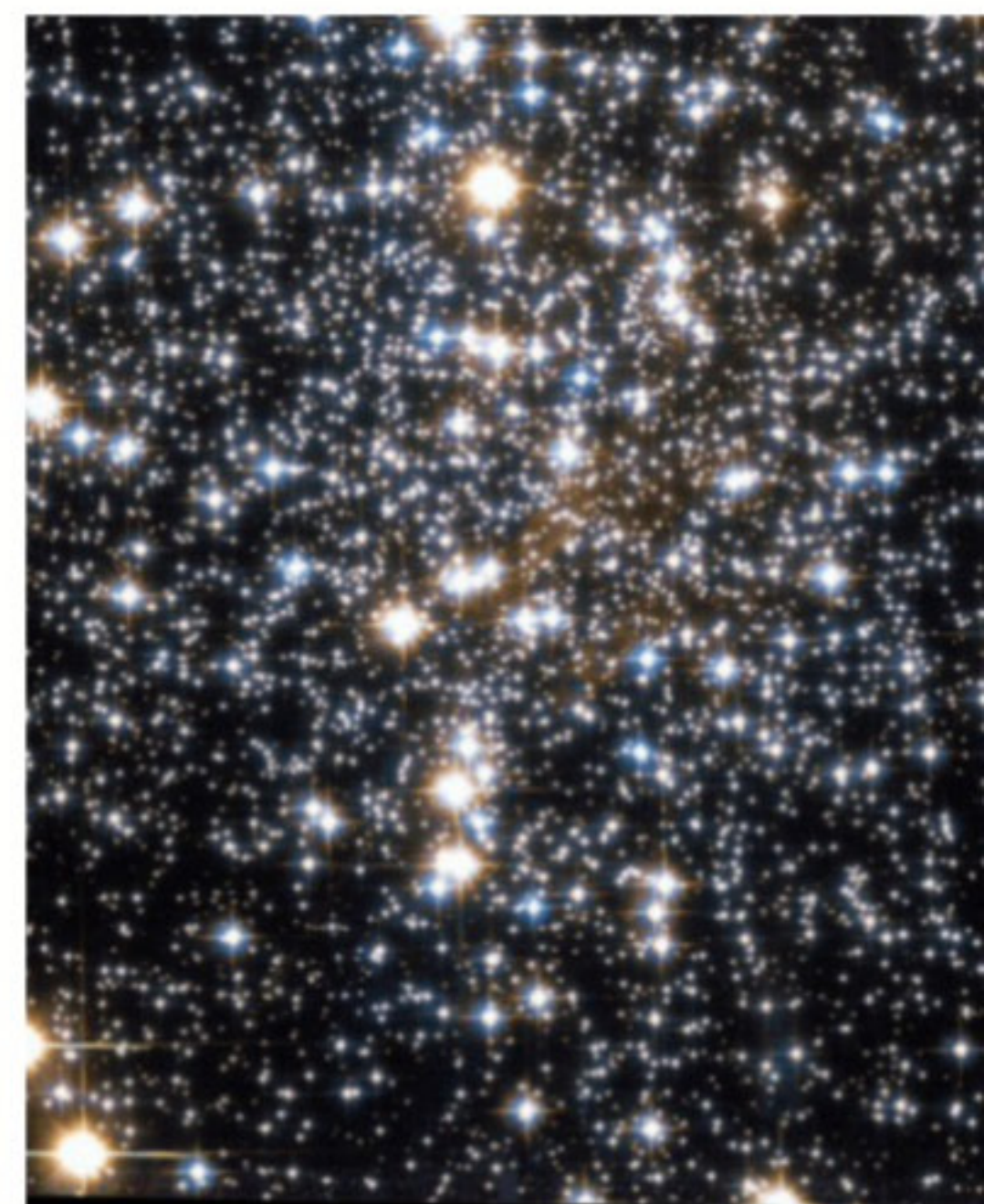
29 M22

Globular cluster

Right ascension: 18h 36m 23.94s

Declination: -23° 54' 17.1"

Minimum optical aid: Borderline
unaided eye



30 M4 Globular cluster

Right ascension: 16h 23m 35.22s

Declination: -26° 31' 32.7"

Minimum optical aid: Binoculars

To end your Messier marathon, we're heading towards the right and the dazzlingly bright and brilliant red star Antares in Scorpius. Just 1.5 degrees to the right and less than half a degree down is M4. Due to its proximity to one of the brightest and best-known stars in the sky, it is one of the most accessible globular clusters. It was the first globular cluster in which astronomers were able to pick out individual stars. If you have a medium-sized telescope you may well be able to do the same. A great way to conclude a night's observing!

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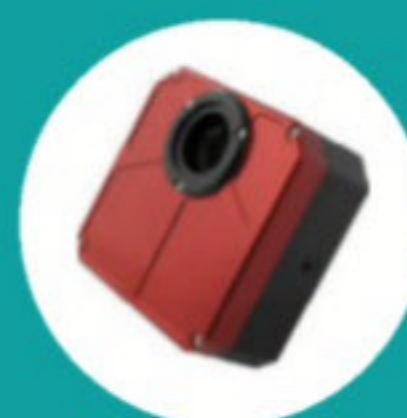
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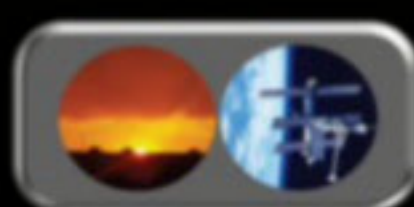


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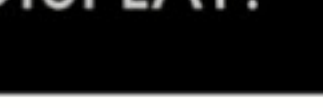
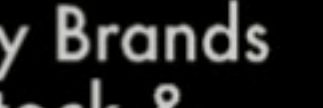
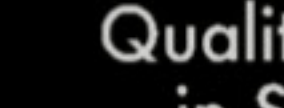
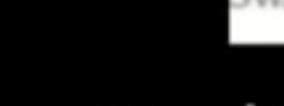
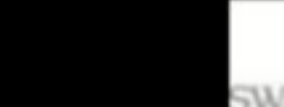
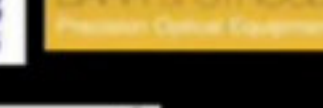
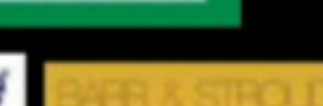
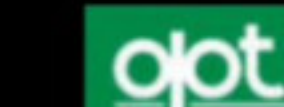
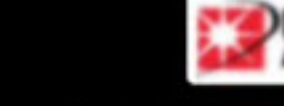
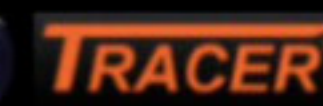
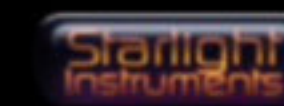
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What's in the sky?

Late winter skies reveal a wealth of wonderful constellations and stunning celestial objects

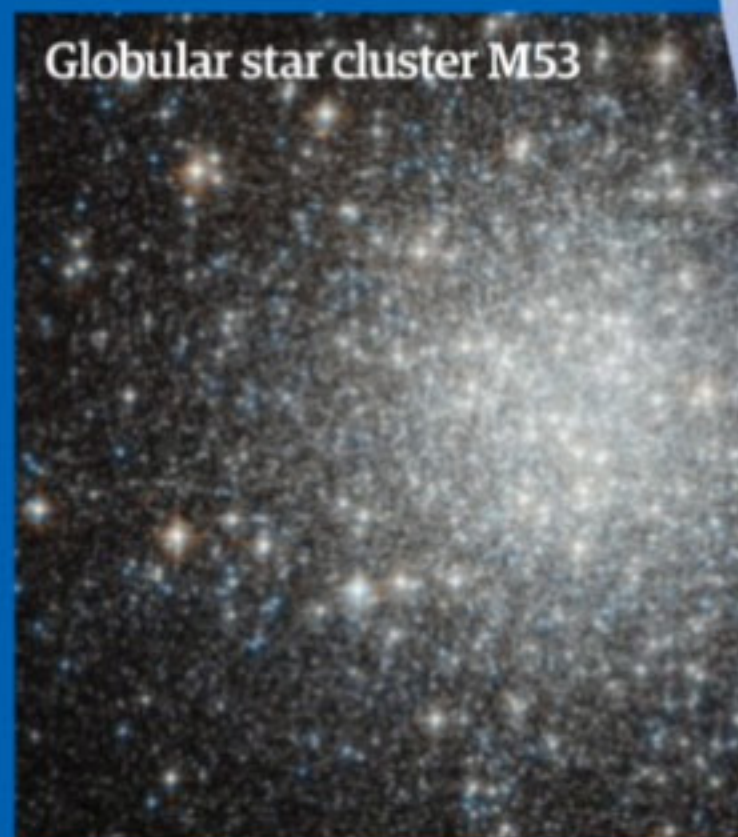
Using the sky chart



Please note that this chart is for midnight mid-month and set for 45° latitude north or south respectively.

- 01 Hold the chart above your head with the bottom of the page in front of you.
- 02 Face south and notice that north on the chart is behind you.
- 03 The constellations on the chart should now match what you see in the sky.

Globular star cluster M53



Globular star cluster, M53

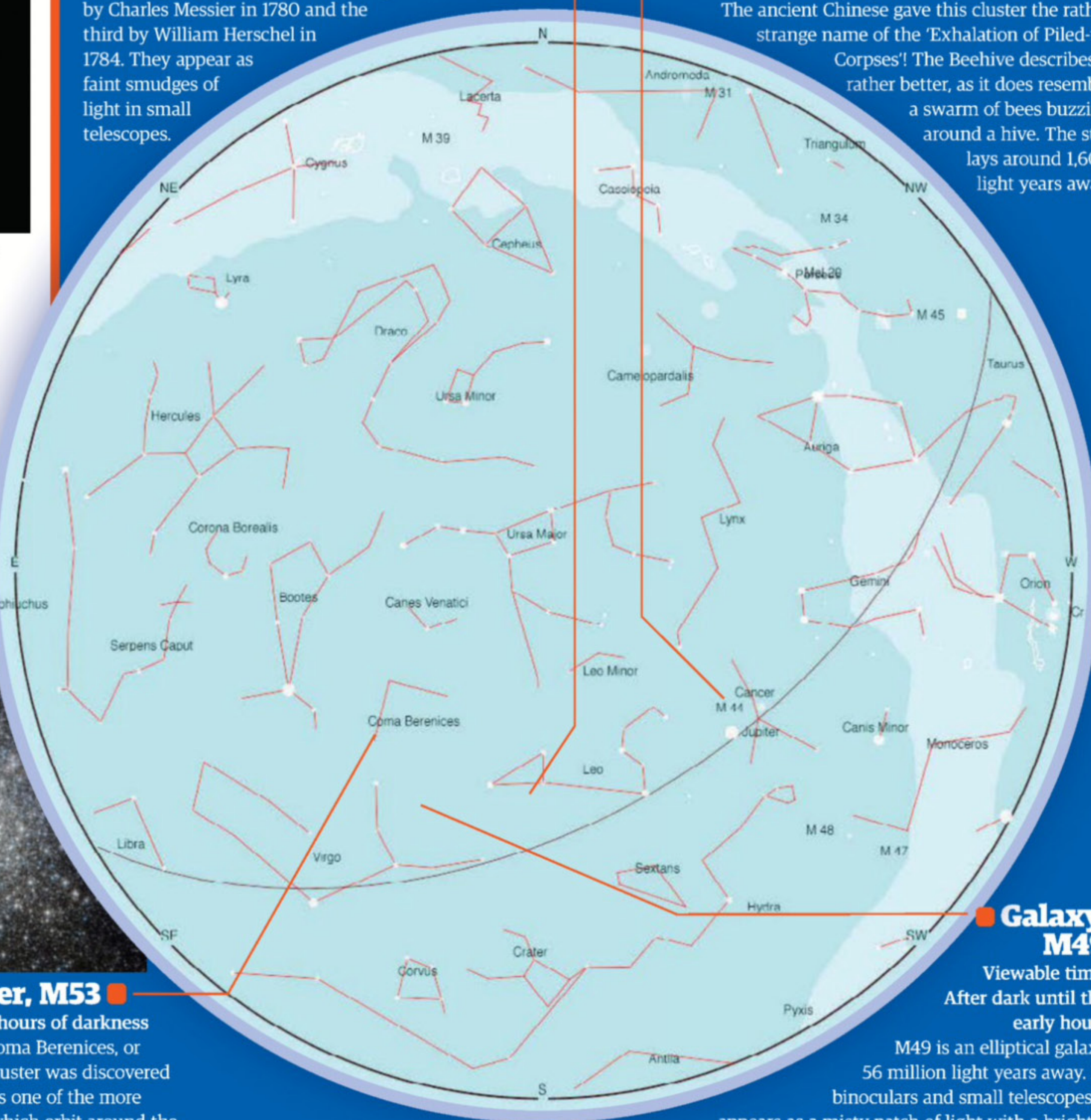
Viewable time: All through the hours of darkness
Located in the constellation of Coma Berenices, or 'Berenice's Hair', this attractive cluster was discovered in 1775 by Johann Elert Bode. It is one of the more distant of the globular clusters, which orbit around the centre of the Milky Way, lying around 60,000 light years away. The stars in this cluster are also very old, being some 12.67 billion years of age. It appears as a fuzzy ball of light in binoculars and small telescopes.

The Leo Triplet

Viewable time: All through the hours of darkness
This is a cluster of three galaxies - M65, M66 and NGC 3628. They are all spirals at differing inclinations, one edge-on and the other two tilted obliquely. They're around 36 million light years away. The two brightest were discovered by Charles Messier in 1780 and the third by William Herschel in 1784. They appear as faint smudges of light in small telescopes.

Open cluster, M44

Viewable time: All through the hours of darkness
Also known as Praesepe or the 'Beehive Cluster', this lovely open cluster lies in the constellation of Cancer (the Crab) and is visible to the naked eye. Binoculars show it up as a group of around 50 gem-like stars. The ancient Chinese gave this cluster the rather strange name of the 'Exhalation of Piled-up Corpses'. The Beehive describes it rather better, as it does resemble a swarm of bees buzzing around a hive. The star lays around 1,600 light years away.



Northern hemisphere

Galaxy, M49

Viewable time: After dark until the early hours
M49 is an elliptical galaxy 56 million light years away. In binoculars and small telescopes it appears as a misty patch of light with a brighter core. It's thought there is a supermassive black hole at its centre. M49 belongs to the Virgo galactic cluster and has many globular clusters orbiting it, but these aren't visible to amateur telescopes.



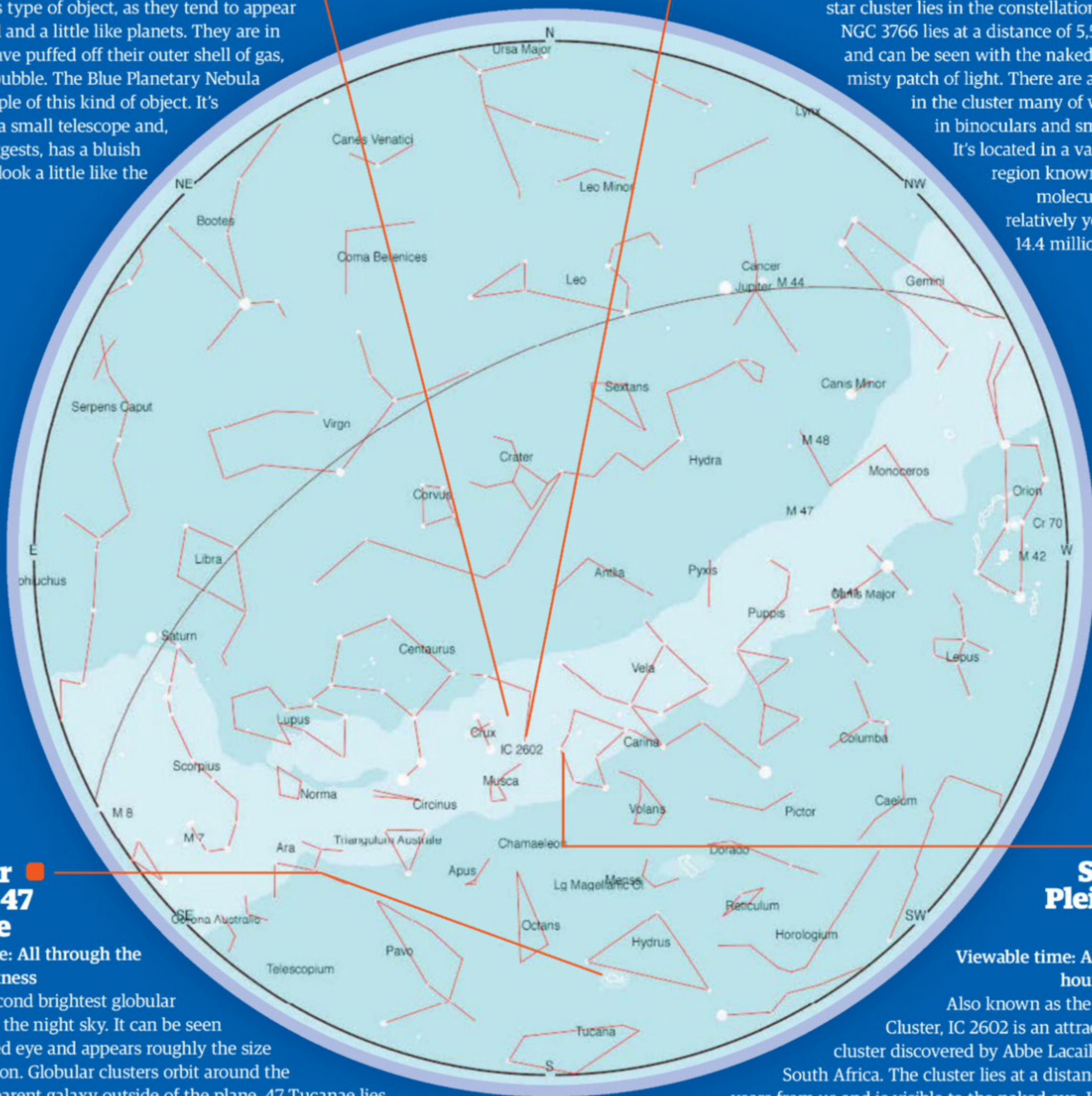
Blue Planetary Nebula

Viewable time: All through the hours of darkness
The name of this object came about due to the first discovery of this type of object, as they tend to appear small and round and a little like planets. They are in fact stars that have puffed off their outer shell of gas, forming a thin bubble. The Blue Planetary Nebula is a lovely example of this kind of object. It's easily visible in a small telescope and, as the name suggests, has a bluish tinge making it look a little like the planet Neptune.

Southern hemisphere

Open star cluster, NGC 3766

Viewable time: All through the hours of darkness
Also known as the Pearl Cluster, this lovely open star cluster lies in the constellation of Centaurus. NGC 3766 lies at a distance of 5,500 light years and can be seen with the naked eye as a small misty patch of light. There are at least 36 stars in the cluster many of which show up in binoculars and small telescopes. It's located in a vast star-forming region known as the Carina molecular cloud. It's a relatively young cluster at 14.4 million years of age.



Globular cluster, 47 Tucanae

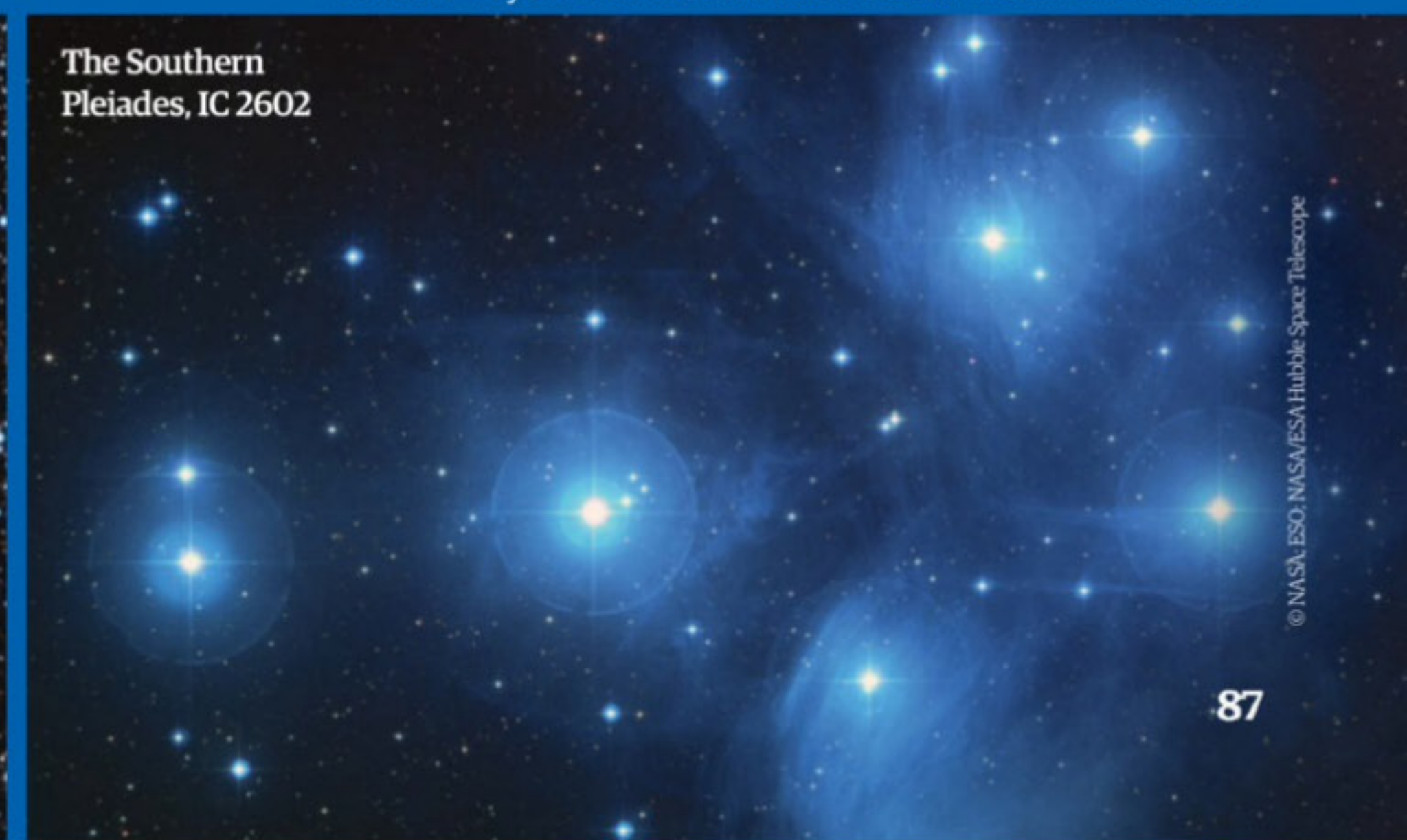
Viewable time: All through the hours of darkness
This is the second brightest globular star cluster in the night sky. It can be seen with the naked eye and appears roughly the size of the full Moon. Globular clusters orbit around the core of their parent galaxy outside of the plane. 47 Tucanae lies 16,700 light years from us. It contains many millions of stars. Binoculars and small telescopes will resolve many of the outer stars in the cluster.

The Southern Pleiades, IC 2602

Viewable time: All through the hours of darkness
Also known as the Theta Carinae Cluster, IC 2602 is an attractive open star cluster discovered by Abbe Lacaille in 1751 from South Africa. The cluster lies at a distance of 480 light years from us and is visible to the naked eye. It's fainter than the northern or Taurean Pleiades but has a similar form. Wide-field binoculars or a small telescope at low power are the best ways to view it. The cluster contains around 50 stars.



Globular cluster,
47 Tucanae



The Southern
Pleiades, IC 2602



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The Pleiades (M45)

Andy Milner



King's Lynn, Norfolk
Telescope: Sky-Watcher
Explorer 200P

"I got into astronomy only in February last year. I've always been intrigued by the night sky, and decided it's about time I got a telescope. It's been a great journey

so far, I've made many friends and gained a huge amount of experience. I am a committee member of my local astronomy society and help online forums such as Astronomy for Beginners (A4B).

"My main passion is astrophotography and I have built up a large range of accessories. These images are either taken with my Canon 1100D DSLR, or with a high-FPS planetary camera."

Andromeda Galaxy (M31)

Comet Lovejoy (C/2014 Q2)

Shamsher Ali



Harlow, Essex

Telescope: Sky-Watcher
250P Dobsonian

"I have always had a keen
interest in astronomy.

However, being a university
student studying biology it
can be challenging and difficult to balance
my time between studying and observing the
sky at night. I currently use my iPhone 6 to
capture the images through the telescope
and Photoshop CS6 to process them.

"My long-term ambition is to
purchase a DSLR camera, this
will enable me to obtain a
detailed image and gain more
exposure. My favourite object
to observe is the Moon - in
particular its beautiful
craters. I would like to
thank a good friend of
mine - James Parker
- who has supported
and guided me to
astronomy."



The Cocoon Nebula (IC 5146)

Steve Nichols



South Ockendon,
Essex

Telescope: Altair Wave
Series 115 Triplet APO

"This is my shot of
the Cocoon Nebula
(IC 5146) in the

constellation Cygnus, which was taken
in Monte Pego in southern Spain while
I was on holiday. I only collected about
an hour's worth of data but I am pleased
with how this image turned out.

"When it comes to astronomy, I
consider myself to be a newbie and
the learning curve is massive but the
rewards are worth it."

Send your photos to...  @spaceanswers  photos@spaceanswers.com



Stargazing stories

Email the story of how you got into astronomy to **photos@spaceanswers.com** for a chance to feature in **All About Space**

Jaspal Chadha



Location: Romford, London

Twitter: @jaspaljk

Info: Astronomer for three years

Current rig

Telescope: Altair Astro RC 250-TT

Mount: iOptron CEM60

Other: Sky-Watcher Esprit 100ED telescope and QSI 690CCD imaging camera

"I have been into astronomy for just over three years now. I spent years looking through various telescopes and eyepieces and enjoyed learning everything about the night sky. During my observations, I loved what I saw and wanted to share what I was able to see with others who were less fortunate to own a telescope - I decided the best way to do that would be through the images I could capture.

"After months of research plus trial and error, I invested in a setup that worked for me. One of my biggest challenges was to fend off the myths about imaging in city light pollution.

"I have spent my life living in London and never thought I could get a sky that's better than its usual light-polluted state - but I was totally wrong! Several hours out of London I was lucky enough to come across the clearest and darkest skies. The

challenge was to produce decent enough images to share, knowing that the light pollution would restrict me, so in the end, I bought a filter and attached it to the front of my imaging train. This helped reduce the light pollution in the images.

"I have also invested in a set of narrow-band filters and since then I have never looked back. These filters are able to cut straight through the light pollution, giving me images that I am extremely proud of.

"For me, astrophotography is very rewarding. You don't need any expensive setup to produce stunning shots and you don't really need to live under the darkest skies in the world (although it would help). If you are looking to break into astrophotography, my advice is to take small steps, learn from your mistakes and keep working towards your goals." ●

"The Wizard Nebula is a diffuse nebula surrounding the developing open star cluster NGC 7380"



"The Bubble Nebula and M52 cluster. This is an emission nebula in the constellation Cassiopeia"



"M82 lies at an estimated distance of 12 million light years in the constellation of Ursa Major"



Jaspal's top three tips

1. Plan your night

Plan your imaging object in advance, use software like Stellarium to plan where your target is going to be in the sky and how much time you get capturing it.

2. Go Moonless for deep sky

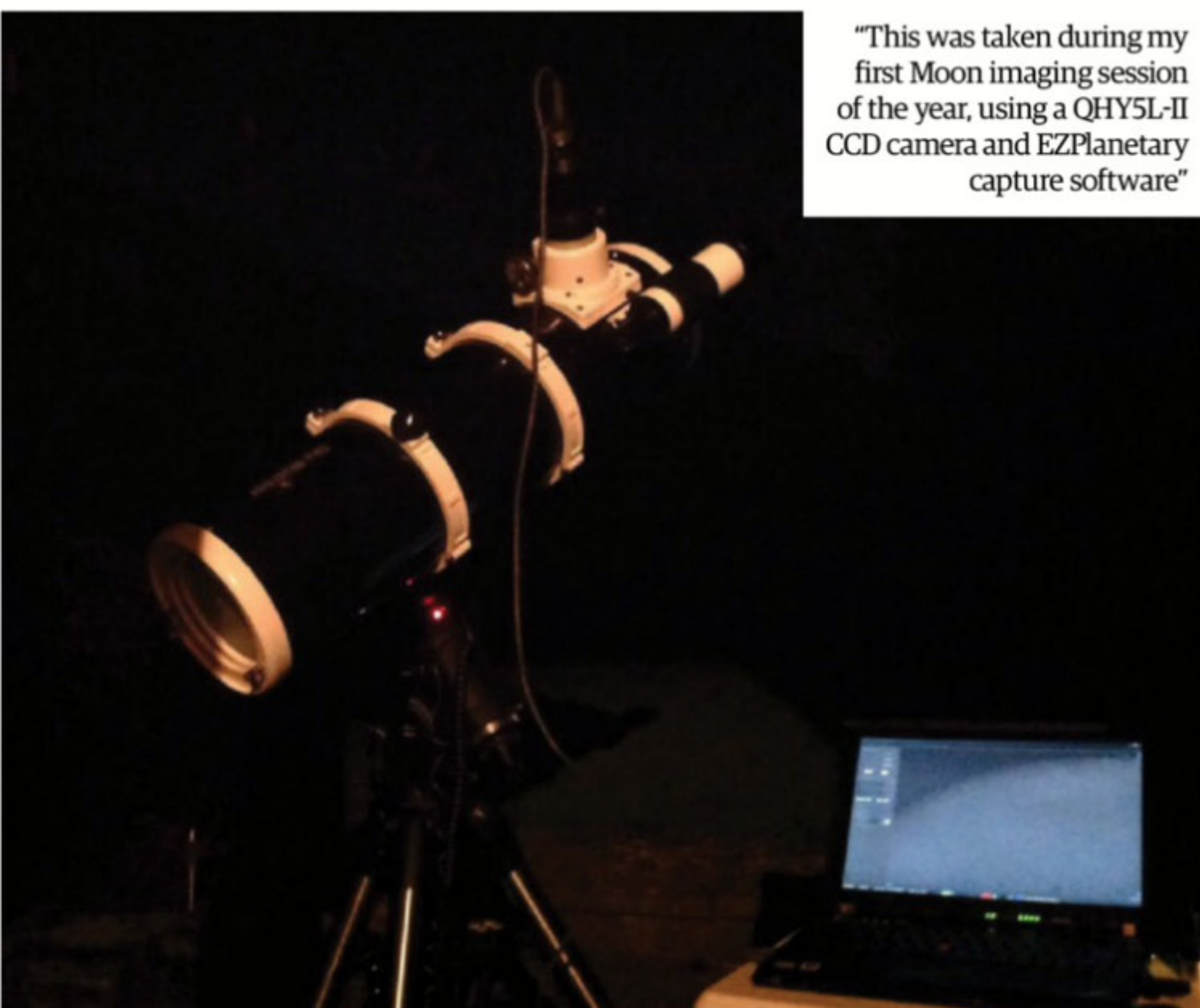
The best time to image faint deep sky objects like galaxies is on a night free of light pollution - from the Moon and artificial sources.

3. Pick the right time

Image when your desired object is just past the meridian line in the sky, that will ensure you have the best sky conditions away from light pollution.

Send your stories and photos to... [@spaceanswers](https://twitter.com/spaceanswers) [@ photos@spaceanswers.com](mailto:photos@spaceanswers.com)

"After upgrading from a modified webcam to a CMOS QHY5L-II camera this was my first Moon mosaic using Microsoft's free ICE tool"



"This was taken during my first Moon imaging session of the year, using a QHY5L-II CCD camera and EZPlanetary capture software"



"My first attempt at my favourite section of the huge emission nebula, the North America Nebula"

Alastair Woodward



Location: Derby, UK

Twitter: @WoowahGeek

Info: Astronomer for two years

Current rig

Telescope: Sky-Watcher 150P and Sky-Watcher 200P Skyliner Dobsonian

Mount: HEQ5 (standard, non Go-To version), with ST4 hand controller mod

Other: Canon EOS 350D, Canon EOS 1000D, Astronomix CLS Clip Filter, QHY5L-II (used for both planetary photography and guiding purposes), Bahtinov mask, solar filter, intervalometer

"My passion for science and technology began at a young age and led me to study computing at university. While always fascinated by the night sky, in particular the Moon, it wasn't until the passing of my father that I started to think further about the existential questions of life. Where better to gain an insight of our being, history and place in the universe, than examining, exploring and photographing the night sky?"

"Two years ago after much deliberation, I purchased a humble six-inch Newtonian reflector on a modest EQ3-2 equatorial mount. Initially, my intentions were to keep strictly to visual observation but after six months I felt I wanted to better record my observations, leading to my interest in astrophotography."

"Given the UK climate I find that being able to set up at a moment's notice is crucial so visits to dark sites haven't been as frequent as I'd like. Instead, my east-facing garden is the spot for both my visual observations

and photographs. However, living only a few miles outside of a city centre does have limitations when observing due to light pollution but the majority of brighter objects can easily be found.

"My appreciation of dark skies was recently boosted when I stayed in a small, inland village located in the south of France. The night skies were the darkest I've seen, with stellar views of the Milky Way. The icing on the holiday cake was that the owner had a 90mm refractor, made available during our stay, resulting in a number of evenings of incredible viewing."

"Social media - such as Twitter and Facebook - does feature heavily in my day-to-day life. My skills and knowledge have greatly increased thanks to interactions with fellow amateur astronomers and astrophotographers using these channels. I still remember the moment Twitter was abuzz with the identification of SN2014J type Ia supernova. This was a very exciting time for me." ■

"The night skies were the darkest I've seen, with stellar views of the Milky Way"

Alastair's top three tips

1. Make use of online resources

There's a wealth of online resources and free tools, from photography manipulation to software, that helps locate and identify objects.

2. Get involved

Join some of the many astronomy-based groups on social media. I have made many new friends and find these groups invaluable for hints, tips and events.

3. The 'homebrew' community

I have embarked on a number of projects - including removal of the IR filter in a Canon 1000D, and the production of a lightbox.



Vixen A70Lf with Mini Porta mount

A good value package for beginners on a budget, this telescope provides clear views of the planets and Moon

Telescope advice

Cost: £358 / \$378

From: Opticron

Type: Refractor

Aperture: 2.8"

Focal length: 35.4"

Best for...

? Beginners and intermediate

£ Low budgets

🔭 Planetary viewing

🌙 Lunar viewing

🌀 Bright deep sky objects

The Vixen A70Lf is a good first telescope for the beginner, since it is not only an extremely affordable starter package but also easy to use and a breeze to set up. Vixen has kept the novice astronomer in mind by making the A70Lf a very portable, 'grab and go' telescope that's no trouble in transporting for a night of observations.

The overall build of the A70Lf is of a high standard for the price, with very good quality cast rings and a versatile Vixen dovetail, which allows you to fit the telescope tube to a variety of compatible mounts. The tripod legs of the Mini Porta mount are perhaps a bit too light, but seem to hold the tube steadily enough for observing, provided you have positioned the telescope on a level surface and treat the entire setup with due care.

Because of its small aperture, the Vixen A70Lf is ideal for observing Solar System targets as well as the lunar surface and we were impressed

with the views, given the refractor's low price. The optical system provided very clear images, which are characteristic of the quality of a Vixen instrument. Observing in an area free of light pollution (apart from that of the Moon), we were able to test the abilities of the A70Lf combined with the very good 20mm and 6.3mm Vixen Plössl eyepieces, which provide magnifications of 45x and 142x, to the maximum. Given that the useful magnification of the telescope is around 143x, we thought that pushing the telescope to such a high magnification using the 6.3mm eyepiece is perhaps a bit too optimistic – especially since the views through this eyepiece are not as clear.

Sadly, the 6x24 finderscope does let the telescope down, meaning that anyone who is very unfamiliar with the night sky will struggle to observe with the A70Lf, despite it being aimed at beginners. Anyone who has used a telescope without the guidance of

a finderscope, will know how long it takes to eventually find the target they have been wanting to observe. Sadly, we couldn't really see any way of attaching a red-dot finder due to a non-standard fitting, so it's likely that you would need to upgrade the A70Lf's finderscope altogether.

Bringing the view into focus did prove to be an effort with the toy-like focuser. Even when we slowly and gently turned the focusing wheel, the image seemed to bounce around the field of view, making it difficult to tell whether the image is focused or not unless we stopped adjusting.

The Moon was in the night sky at the time we tried this telescope, so we took advantage of observing its cratered surface and were very pleased with the A70Lf's clarity. Given that the telescope is an achromat and has a relatively long focal length, there isn't any pesky chromatic aberration, or colour-fringing, to speak of around bright objects such as our lunar companion or Jupiter, which reached opposition in early February. Views of



The alt-azimuth mount is easy to use and moved quite smoothly

"Views of Jupiter were clear and we could just about make out the planet's bands"

The Vixen A70Lf is compact, promoting a high degree of portability and making it ideal for beginners to astronomy

the gas giant were clear and we could just about make out the planet's bands along with four of its largest Galilean moons - Io, Ganymede, Europa and Callisto. Turning the A70Lf to the Orion Nebula (M42), we could see the structure of this beautiful star-forming region very clearly and the members of the Trapezium star cluster found at the nebula's heart were easy to see. Observing any other deep sky objects, which are particularly diffuse and have a magnitude fainter than +4, is a struggle for this telescope due to its small aperture and therefore its ability to collect enough light.

Despite its drawbacks, the Vixen A70Lf combined with the Mini Porta mount is versatile when it comes to accessorising with eyepieces, provided you don't push the refractor too close to its magnification limit. What's more, and provided you can find a higher-quality finderscope, this refractor is an ideal telescope for children and novice astronomers given its ease of use and reasonable price for those on a budget. ■



The image seemed to bounce around the field of view, no matter how gently we used the focuser to bring our chosen target into focus



Eyepieces with a focal length of 20mm and 6.3mm are supplied with the Vixen A70Lf



Star diagonals

For a comfortable viewing experience through your telescope, we put two star diagonals head-to-head

Altair Astro 2" dielectric diagonal

Cost: £69.99 / \$N/A

From: Altair Astro

With its excellent build and a barrel that adapts to both 2" and 1.25" - to ensure attachment to a wide selection of eyepieces and filters - we are impressed with the quality of the Altair Astro diagonal. The attractive and resistant dielectric coating not only gives this piece of astronomy kit a beautiful finish, but it also promises to last for many years of observations.

It's also good to see threading within the 2" barrel, which allows a

variety of filters to be fitted. When we slotted the diagonal into our in-house refractor, we appreciated the secure fit and enjoyed views untouched by stray light reflection, for high contrast when observing.

The diagonal did the job when it came to viewing, and made observing through our refractor all the more comfortable. Eyepieces and filters fitted snugly for a steady view of both Solar System and deep sky objects.

Ostara 2" dielectric diagonal

Cost: £99.99 / \$N/A

From: Optical Hardware Ltd

With its sleek finish, this diagonal from Ostara is pleasing to the eye and is very sturdy to the touch. The barrels are of high quality, promising a long life and many observing sessions to come. Removing the 1.25" attachment, we were disappointed to find that there was a mass of sticky residue where the optical system has been stuck together.

This didn't affect the functionality of the diagonal and we achieved

pleasing and comfortable views through Ostara's piece of kit, combined with the telescope's excellent optical system. We were able to slot our eyepieces in with ease and without damaging their barrels, however, we were quite disappointed with the price of the diagonal, especially since you can buy other diagonals that do exactly the same job to a high standard elsewhere on the market.



Verdict

Winner: Altair Astro 2" dielectric diagonal

Some may prefer the sleek finish of the Ostara diagonal to match their instrument, but the look of the instrument aside, we do prefer the diagonal produced by Altair Astro.

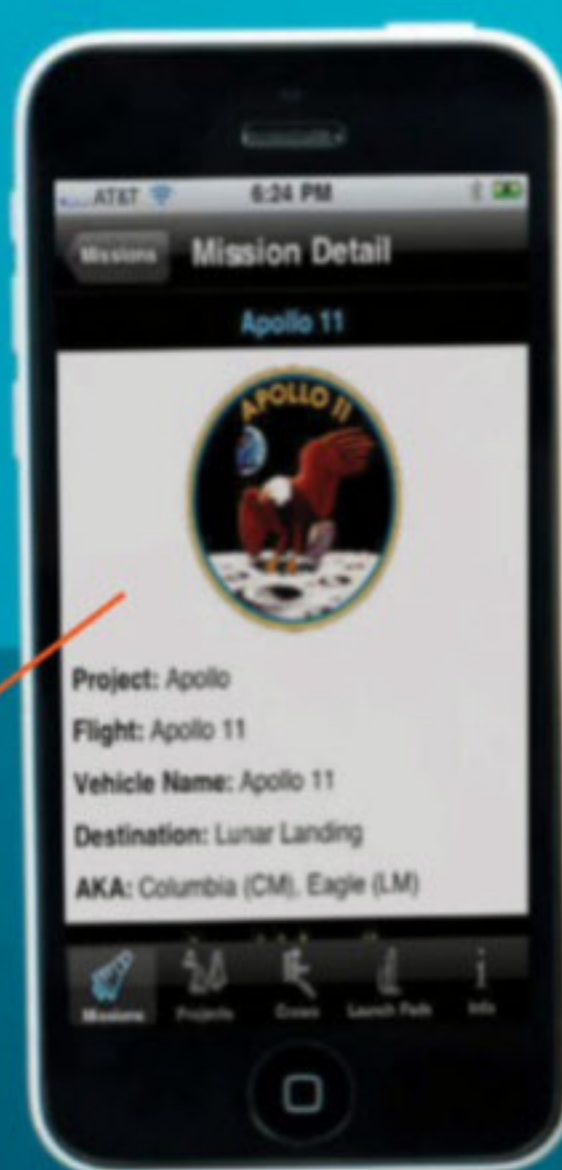
Not only is this accessory's optical system of higher quality build, the cost is lower too, giving you a little more budget to purchase other pieces of kit for your hobby.





Astronomy kit reviews

Stargazing gear and accessories for astronomers and space fans alike



1 App Space App

Cost: Free

From: iTunes

We can't say that we were massively impressed with the design and general layout of Space App, an educational resource that provides you with information on spaceflight programmes of the United States, Russia and China. The app provides a lot of data and the information is only a few taps and a swipe away.

We found Space App to be very easy to use but did feel that there was a lot of technical data that wouldn't interest much of its target audience. For instance, we're much more intrigued by the landing speeds than the maximum dynamic pressure. All in all, there's plenty there that will keep the spaceflight enthusiast happy - that is until they reach the year 2011. Data for anytime beyond this point is non-existent. Despite this, we like the thought behind listing the crews of each spaceflight mission in Space App as well as the pages detailing each of the missions. ●

2 Book Galaxy: Mapping The Cosmos

Cost: £20 / \$35

From: Reaktion Books Ltd

James Geach, a professional astronomer at the University of Hertfordshire, has made understanding what we believe to be the origins of our universe incredibly easy in his book *Galaxy: Mapping The Cosmos*. What we love about it in particular is that, while it might look heavy-going in terms of its content, this is far from the truth - you don't even need a science background to understand Geach's writing.

Throughout the text, he has focused on the formation and evolution of galaxies but has tied its relevance into the story of how our universe came into existence. What's more, there are some stunning images of galaxies and clusters throughout the text, giving the reader an excellent view as to what is really out there in the cosmos.

Beautifully written and engaging to read, *Galaxy* is a book that we can strongly recommend. ●

3 Eyepieces Ostara Flat Field eyepieces

Cost: £99.99 each / \$N/A

From: Optical Hardware Ltd

With our first use of these eyepieces, we immediately appreciated the wide field of view along with their ability to provide crisp and clear images of Solar System targets with ease. However, these eyepieces might be on the expensive side for the beginner.

Being 1.25", these eyepieces can be used with many telescopes so we tested the 8mm, 12mm, 19mm and 25mm in more than one in-house telescope. We found that the 'Flat Field' element of these eyepieces is evident, with curvature in the short focal length very well compensated for to provide a flatter and much more pleasing view over standard Plössls.

With added multicoating, these eyepieces kept reflections at bay when it came to looking at bright targets, while picking out an assortment of fainter night sky objects. The eye relief of these Ostara eyepieces is also very good for those who wear glasses. ●

4 Adapter Olivon smartphone camera adapter

Cost: £59.99 / \$N/A

From: Optical Hardware Ltd

It might not be much to look at, but the Olivon smartphone camera adaptor is an incredibly useful piece of kit for the astrophotographer who prefers to use their smartphone to image the night sky.

Slotting an iPhone into adjustable 'prongs' and attaching it to the end of a telescope to ensure that it is securely fitted, we were pleased to find that the entire setup is very sturdy, while allowing a degree of movement to enable the user to shoot in a landscape or portrait orientation.

We imaged the lunar surface using this device and are pleased with the result as it picked out a few craters and lunar mare. Images are crisp and clear, proving that there is no degree of shaking or unsteadiness that holding your phone up to the eyepiece with just your hand can cause. This adapter is certainly worth the price to go hands-free! ●

WIN WIN A TELESCOPE BUNDLE WORTH OVER £1000!

We've got everything you need to get started in astronomy with our latest competition

Buzz Aldrin's Space Program Manager

From: slitherine.com

Cost: From £20.99 / \$29.99

Straddling between an accessible management sim and informational game, *Buzz Aldrin's Space Program Manager* is a simple simulation that sees you take charge of a Fifties space agency, training, upgrading, and launching new missions. Ideal for casual gamers. (Tablet device not included.)

Ostara Flat Field eyepieces

From: Optical Hardware Ltd

Cost: £99.99 (approx. \$154) each

View a selection of night-sky gems using these Flat Field 1.25" eyepieces (8mm, 12mm, 19mm and 27mm). Made to a high standard and providing superb views, this range from Ostara is suitable for a wide variety of telescopes and will provide you with more pleasing images of planetary targets and deep-sky objects than standard Plössl eyepieces.

To be in with the chance of winning, all you have to do is answer this question:

NASA's Chandra X-ray Observatory is named after who?

A: Lalitha Chandrasekhar

B: Chandrasekhara Venkata Raman

C: Subrahmanyan Chandrasekhar

Enter online at: spaceanswers.com/competitions Visit the website for full terms and conditions

Ostara seven-piece visual filter set

From: Optical Hardware Ltd

Cost: £59.99 (approx. \$93)

Enhance your views of the Solar System with this seven-piece filter set, includes Moon, Polarising, Yellow, Orange, Red, Green and Blue filters for an observing experience like no other. If you want to see one of Mars's dust storms, Jupiter's Great Red Spot or the craters of the Moon, Ostara's visual filters can be used with most telescopes.



■ Visionary Mira Ceti 150 1400 telescope

From: Optical Hardware Ltd

Cost: £299.99 (approx. \$463)

With its six-inch aperture, the Visionary Mira Ceti is the perfect companion to observe a wide range of night-sky targets, from planets to deep-sky objects. Complete with 25mm and 6.5mm eyepieces, as well as a Barlow lens and Moon filter, this compact and light Newtonian offers good portability.

■ The Practical Astronomer

From: Dorling Kindersley

Cost: £14.99 / \$19.95

Written by astronomers Anton Vamplew and Will Gater, *The Practical Astronomer* helps you pick up all the basics of skywatching. Starting off your tour of the night sky simply, this book shows you how to recognise constellations and identify deep-sky and Solar System targets. *The Practical Astronomer* also provides advice on buying and using kit, from binoculars to telescopes.

**WORTH
OVER
£1000!**

■ Visionary HD 10x50 binoculars

From: Optical Hardware Ltd

Cost: £109.99 (approx. \$170)

Tour the night sky in high definition with these Visionary HD binoculars, ensuring bright images and excellent light gathering to pick out star clusters to the brightest planets. The 10x magnification allows these binoculars to double up as an aid for nature watching, ensuring high clarity, high power and a natural well-balanced image thanks to multicoated lenses and BAK4 prisms.



■ Turn Left At Orion

From: Cambridge University Press

Cost: £24.99 / \$34.99

A must-have for any observer, *Turn Left At Orion* is a guidebook to the night sky, providing all the information needed to observe a host of celestial objects. Featuring a spiral bind, this edition is easy to use outdoors while using a telescope and is ideal for beginners - whatever observing equipment you have, whichever hemisphere you are in.

■ Field Optics Research Eyeshield

From: Optical Hardware Ltd

Cost: £19.99 (approx. \$31)

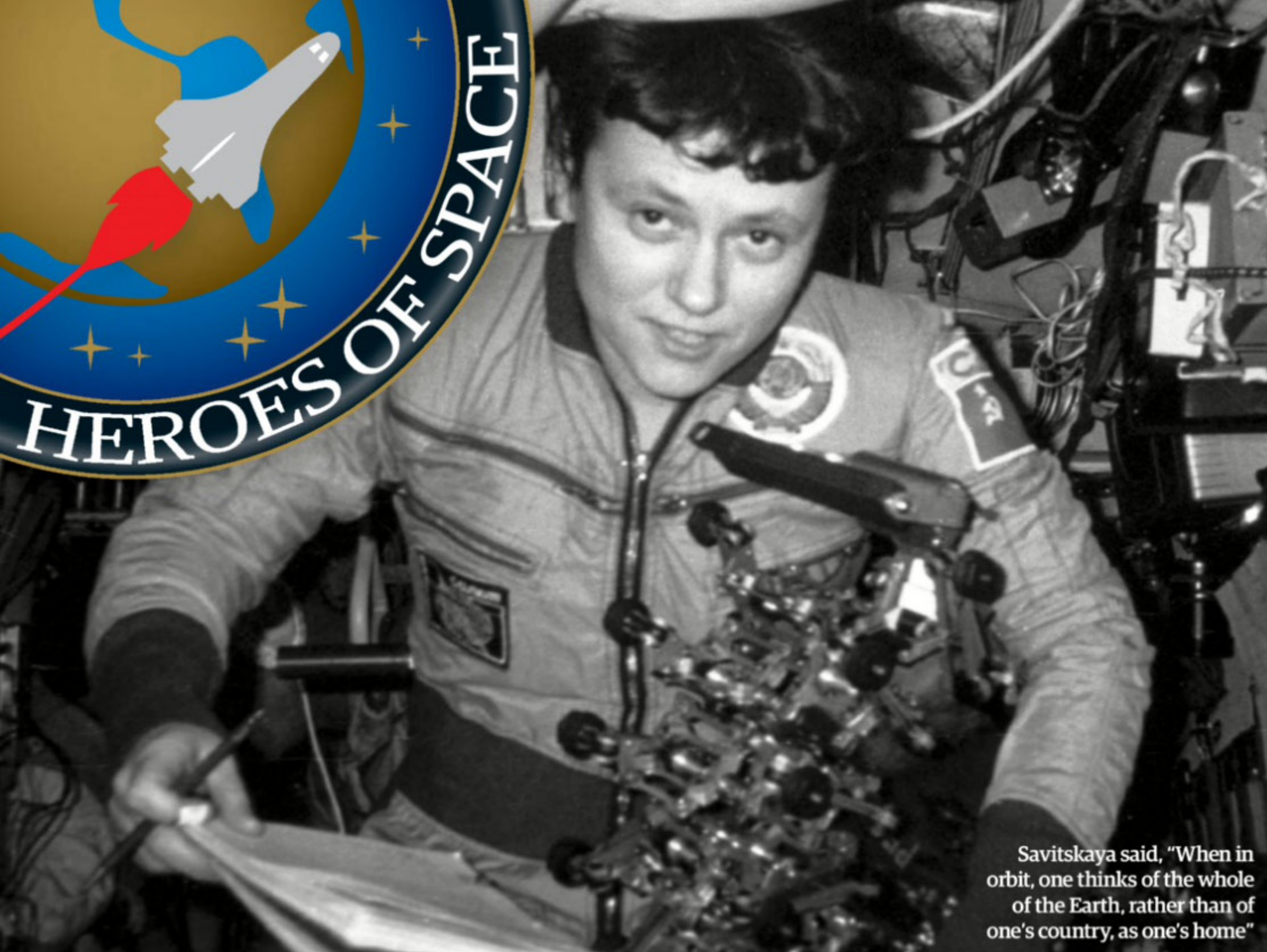
An excellent product for anyone using binoculars or a telescope, the Eyeshield - made using a flexible moulded rubber material - fits comfortably around the eyes to block out any distracting light and wind, providing the skywatcher with total darkness and complete comfort for an outstanding observing experience.

■ Visionary Wetland 8x42 binoculars

From: Optical Hardware Ltd

Cost: £99.99 (approx. \$154)

If you're an avid observer of the Moon, or general nature viewer, then these high-quality waterproof binoculars from Visionary are your ideal companion. Featuring twist eyecups along with coated lenses for great clarity and colour, the Visionary Wetland 8x42 binoculars can withstand the tough outdoors while also remaining light and easy for comfortable observing.



Savitskaya said, "When in orbit, one thinks of the whole of the Earth, rather than of one's country, as one's home"

Svetlana K Savitskaya

Paving the way for female cosmonauts

When Valentina Tereshkova embarked on her groundbreaking flight on Vostok 6, she became the first woman to fly in space. Although this was a momentous occasion, the door to space exploration was still a difficult one for female cosmonauts to prise open, and it took 19 more years for another woman to fly into space. This woman was Svetlana Savitskaya.

The stars seemed aligned for Savitskaya's success as a cosmonaut, as she was the daughter of a Soviet war hero. Yevgeniy Savitsky served as commander of the Soviet Air Defence Forces, had been a flying ace in WWII and was regarded as a national hero. Under her father's influence and by age 16, Savitskaya decided that she wished to become a pilot.

Headstrong and driven, after her application to join a flying school was rejected due to her young age she began to secretly take parachute training instead. It did not remain private for long as her father discovered her parachute knife stashed in her school bag. Far from being angry, her father actively encouraged her interest and by the age of 17 she had completed 450 parachute

jumps. She was finally able to begin the pilot training she so desperately desired at 18, when she enrolled in the prestigious Moscow Aviation Institute.

During her time studying at MAI she joined the Soviet National Aerobatics Team and became a world champion, even catching the attention of the British press who dubbed her 'Miss Sensation' in 1970. When she graduated from MAI she took up work as a flight instructor, but her true aim was to test aircraft and she attended school to do just that. Yet again Savitskaya flew through the ranks and set world record after world record. She qualified to fly on 20 different types of aircraft and was certified as 'Test Pilot, Second Class.' By 1976 she was a test pilot for the Yakovlev Design Bureau, a Soviet aircraft manufacturer.

In 1980, the USSR was keen to launch its own female team of astronauts in opposition to NASA's plans for female astronauts on the Space Shuttle and Savitskaya became part of this group. Although her family connections aided her selection, she completed a full course of training for flight missions and earned her place as a key member of the team.

Ten months before Sally Ride would become the first American female astronaut in space, Savitskaya became the second woman and 53rd cosmonaut in space. On 19 August 1982, Savitskaya and two others flew the Soyuz T-Z spacecraft to the Salyut 7 space station and conducted several experiments. After nearly eight days they returned to Earth.

Two years later, in July 1984, Savitskaya engaged in her second spaceflight on the Soyuz T-12. During this flight she performed an EVA (extravehicular activity) to conduct welding experiments on Salyut 7. This was the first time a woman had ever walked in space, and she also became the first woman to enter space twice. Soyuz T-12 returned to earth after 11 days, 19 hours and 14 minutes.

It was to be Savitskaya's last time in space. There were plans for her to command an all-female crew to Salyut 7 on International Women's Day, but this was cancelled due to problems with the station. Savitskaya eventually retired from the cosmonaut corps in 1993 and now, in her sixties, serves as deputy chair of the Committee on Defence. During her illustrious career Savitskaya received a multitude of awards, including the Order of Lenin and Hero of the Soviet Union, twice, as well as the Order of the Badge of Honour. Savitskaya's total time in space was relatively short - 19 days, 17 hours and six minutes - but her contributions towards female astronauts, space exploration and research as a whole, are remarkable. ■

All About Space

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